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ABSTRACT

This document consists of materials for a 12-unit course on the following topics: (1) introduction to precision measurement; (2) semiprecision linear measurement; (3) simple layout techniques; (4) measurement with vernier and dial calipers; (5) measuring with micrometers; (6) measurement and layout on a surface plate; (7) go/no-go inspection methods; (8) common drafting symbols; (9) blueprint interpretaion; (10) tolerances and allowances; (11) geometric dimensioning and tolerancing; and (12) part layout and machining sequence. The instructor's guide begins with a list of competencies covered in the module, descriptions of the materials included, an explanation of how to use the materials, and information on how the curriculum guide is packaged. Next is a table that associates individual instructional materials in the units with the competencies they teach. The instructional units follow, each of which may include unit objectives, lesson objectives, lesson plans, references, notes to the teacher, information sheets or outlines, transparency masters, handouts, assignment sheets, job sheets, unit tests, and answers to tests. (CML)

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MACHINE SHOP CURRICULUM

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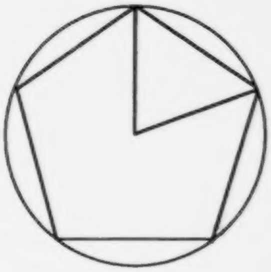
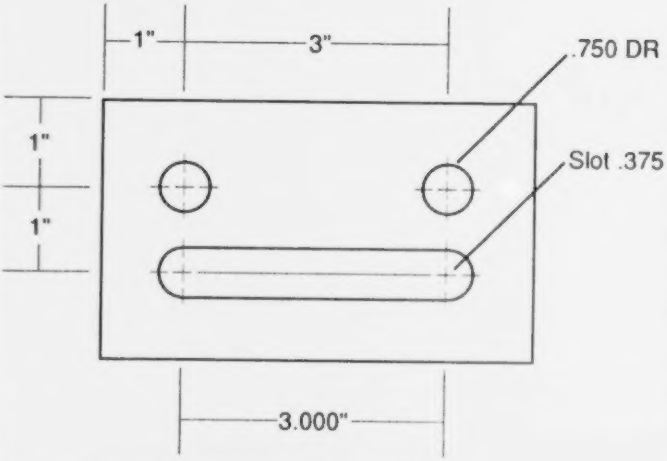
INSTRUCTOR'S GUIDE

MODULE 2: *Measurement and Blueprint Reading*





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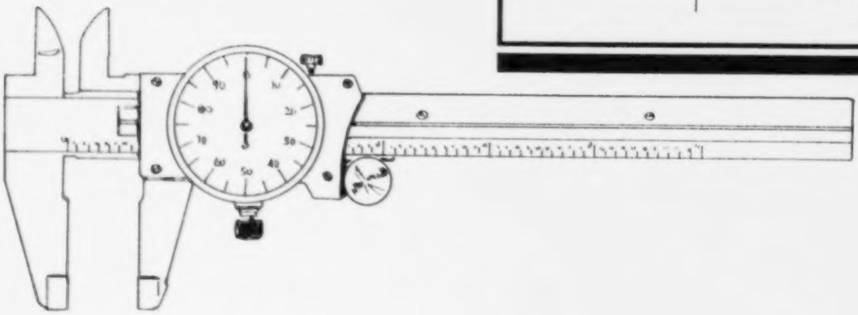

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1: *Machine Shop Orientation and Math* by Donna Curtis and Jack Nobles
2: *Measurement and Blueprint Reading* by Charles H. Walden, Don Marquardt and Henry "Junior" Cagle
3: *Bench Work and Material Science* by Charles H. Walden and Jack Nobles
4: *Power Saw and Drill Press Operation* by Charles H. Walden and Bill Daniel
5: *Lathes* by Jack Nobles
6: *Milling* by Charles H. Walden
7: *Grinders* by Jack Nobles and Mel Gage
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MACHINE SHOP

Module 2: Measurement and Blueprint Reading

by

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1989

Instructor's Guide
Catalog No. 70-6172-I

FOREWORD

Once again, we are indebted to the teachers and administrators who provide their time, efforts and professionalism to develop curriculum for trade, technical and industrial education programs. This Machine Shop guide is an outstanding example of what can be accomplished when the right people with the right attitude get together. Committee members worked hard over several years' time in advisory, writing, technical consultation and field-test capacities.

This guide is designed to be totally integrated with the Vocational Instructional Management System. It is hoped that all guides produced under our supervision will help classroom teachers manage instruction. A curriculum guide is more than a resource--it is an integral part of the management system. Rather than impeding instruction, it should guide and facilitate instruction.

This guide's format has been set up for competency-based teaching and testing. Unit tests evaluate specific competencies and can be used with the Vocational Administrative Management System (VAMS). Information sheets, transparency masters, job sheets, assignment sheets and test items are keyed to specific competencies. A cross-reference table has been included to quickly identify parts of the curriculum that relate to specific competencies. The material has also been packaged for students.

Although this guide may be a new format for some teachers, we are confident that, when used as designed, time spent by teachers and students will become more productive. Any future machine shop curriculum modifications will begin with this guide. The machine shop field is undergoing considerable change. We will annually evaluate the need to update this guide on a module-by-module basis. Your suggestions regarding areas for improvement are both encouraged and appreciated.

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Department of Elementary and Secondary Education

Charles "Chuck" Waibel, director
Industrial Education
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ACKNOWLEDGMENTS

This Machine Shop guide represents a continuing commitment to Missouri's Vocational Instructional Management System (VIMS). The guide has been keyed to the machine shop competency profile developed by industry and education professionals in the state.

Appreciation is given to the writers (Charlie Walden, Jack Nobles, Dwight Crosswhite, Donna Curtis, Don Marquardt, Bill Daniel, Mel Gage and Jr. Cagle) for their technical expertise. Catherine Smith of Dodge Art Works, Columbia, created a large portion of the guide's artwork.

These industry representatives and educators contributed to the guide as members of the advisory committee.

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Support and contributions of IML staff members were instrumental to this module's development.

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Phyllis Miller and Dan Stapleton, assistant directors
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COMPETENCIES ADDRESSED IN THIS MODULE

C. Performing Precision Measurement

1. Care for precision instruments
2. Measure workpiece with tape measure
3. Measure workpiece with pocket rule
4. Measure workpiece with slide caliper rule
5. Lay out work with combination square
6. Transfer measurement with dividers
7. Lay out workpiece with hermaphrodite calipers
8. Measure workpiece with spring calipers
9. Measure workpiece with vernier caliper
10. Measure workpiece with depth gages
11. Measure workpiece with micrometers
12. Measure workpiece with dial calipers
13. Measure workpiece with telescope and hole gages
14. Check work with gages, i.e., plug and ring gages
15. Measure workpiece with height gages
16. Lay out workpiece and measure on surface plate
17. Measure workpiece on surface plate
18. Measure workpiece with gage blocks
19. Measure workpiece with dial indicators and attachments
20. Measure workpiece with thread wires and micrometers
21. Check and/or lay out workpiece with sine bar

D. Blueprint Reading

1. Interpret meaning of common drafting symbols
2. Interpret blueprint
3. Make a sketch from a finished workpiece
4. Calculate tolerances and allowances
5. Calculate missing dimensions
6. Use geometric dimensioning and tolerancing
8. Lay out a part based on blueprint information

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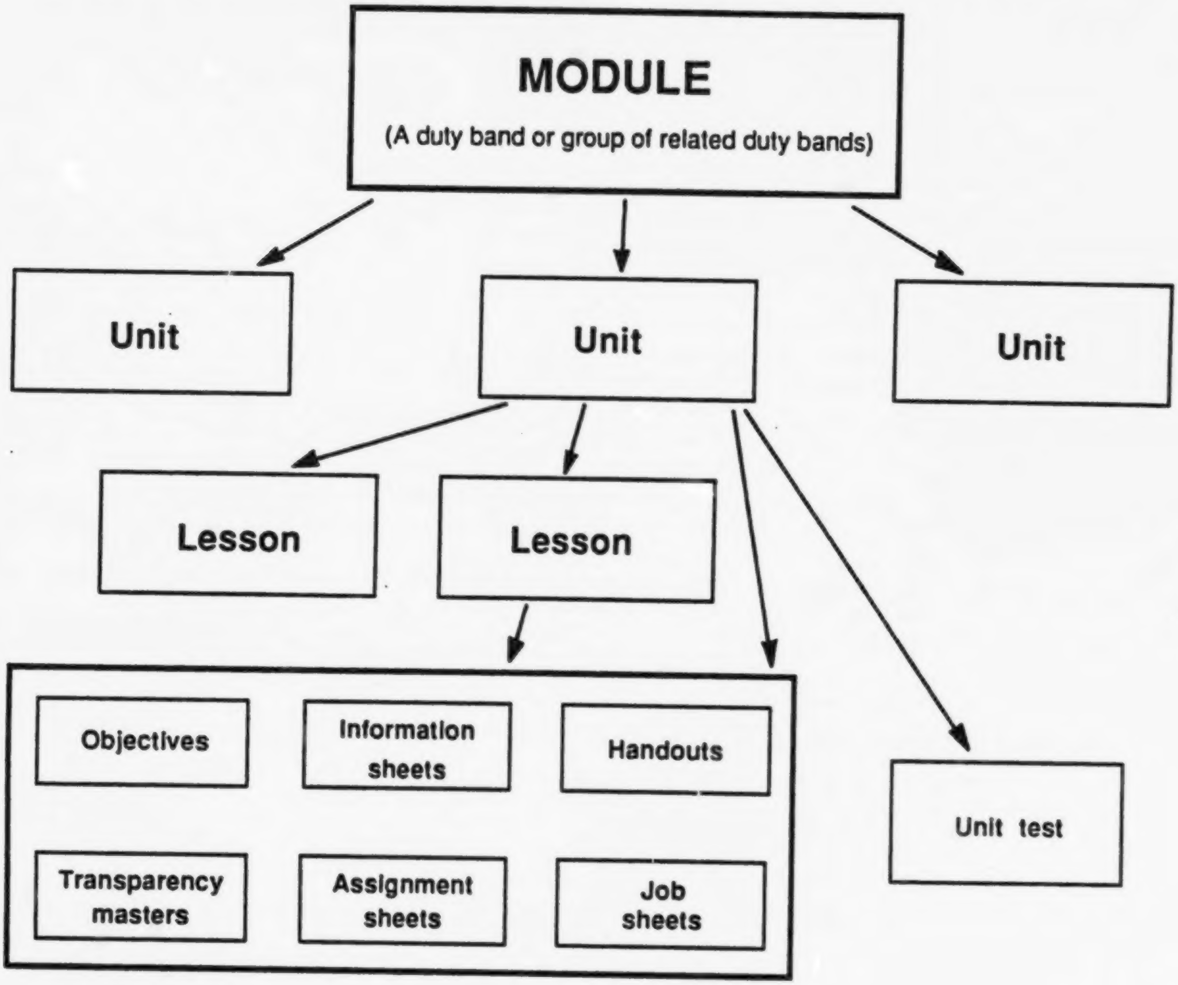
HOW TO USE THIS PUBLICATION

GUIDE COMPONENTS

Units of instruction

This Machine Shop guide contains eight modules of instruction. Within each module are instructional units including some or all of the following components: performance objectives, information sheets, transparency masters, handouts, assignment sheets, job sheets and a unit test. Special instructions on audiovisuals, supplies, etc. are included in the Notes to the Instructor section near the beginning of each unit.



Competency profile

On the Missouri competency profile, tasks are divided into general subject areas, or duty bands, which are identified by a capital letter. Under each duty band are related tasks (competencies), which are identified by an Arabic numeral. To evaluate the student on performance of the competencies, a 3-2-1-N grading system is used, where:

3 = **Mastery** - can work independently with no supervision
2 = **Requires supervision** - can perform job completely with limited supervision
1 = **Not mastered** - requires instruction and close supervision
N = **No exposure** - no experience or knowledge in this area

Cross-reference table (color-coded white)

Once the numbering system is understood, this table quickly reveals how the instructional components of the module relate to Missouri competencies. On the competency profile, tasks are divided into general subject areas, or duty bands, which are identified by a capital letter. Under each duty band are related tasks (competencies), which are identified by an Arabic numeral.

On the cross-reference table, unit numbers are represented by Roman numerals (I, II, III, etc.). Lessons within a unit are shown with Arabic numerals. Therefore, the first objective in Lesson 1 is numbered 1.1, the second is 1.2, and so on. Other components of the module (transparencies, handouts, assignment sheets and job sheets) also use this numbering system. By looking at the cross-reference table, the instructor can quickly determine what test questions or job sheets a student needs to receive an evaluation on a particular competency.

Objectives (color-coded white)

Each unit is based on performance objectives which state the measurable unit and specific behavioral or performance objectives that students are expected to achieve. Since the objectives of the unit provide direction for the teaching-learning process, it is important for the teacher and students to have a common understanding of the objectives' intent. Teachers should feel free to add/adapt objectives which will fit the material to student and community needs. Supporting material will, of course, need to be added for any new objectives.

Table of contents, references, notes to the instructor (color-coded pink)

These pages have been coded pink for instructor use only. The reference section lists materials used as sources in developing the material. Special instructions on audiovisuals, supplies, etc. are included in the Notes to the Instructor section.

Information sheets (green)

Presented in outline form for clarity, these pages provide content essential for meeting the cognitive (knowledge) objectives in the unit. Students should study the information sheets before class discussion or completion of assignment sheets. **CAUTION** statements indicate possible equipment damage or bodily injury. Handouts and transparency masters have been keyed in the information sheets for instructional use.

Transparency masters (white)

Transparencies provide information by visually reinforcing or clarifying ideas presented in the information sheets. They are effective when identification is necessary and direct the class's attention to the topic of discussion. Transparencies should be left on the screen only when topics shown are under discussion, however.

Handouts (white)

Whenever more detailed information than can be presented in a transparency is needed, a handout is used. Handouts give the students additional information that can be kept with their class notes or student references.

Assignment sheets (tan)

Assignment sheets furnish paper-and-pencil practice to develop the knowledge necessary as a prerequisite to skill development. They can be given to students for class completion or used as homework assignments. Answer sheets (color-coded pink) can be used by the student or instructor to check progress.

Job sheets (blue)

These evaluation instruments are provided for two purposes: to outline steps of procedure and to check student performance mastery. Job sheets begin with a list of tools and materials needed for the activity. Job sheets furnish potential employers with a picture of skills being taught and performance which might be reasonably expected from a vocational student. The spaces to the right of the page on a job sheet assist the instructor in evaluating a student on a particular activity. This 3-2-1-N grading system is the same as the one used on the competency profile.

Unit test (yellow)

Competency-based tests are designed to help eliminate subjective testing and to improve student evaluation and accountability. Specific competencies and test questions are linked on the answer key. These unit tests have been written to be used with computerized VAMS (Vocational Administrative Management System), utilizing Scantron sheets for computer-recording of test answers.

The unit test may be eliminated if the competency was thoroughly evaluated by job sheets. However, an emphasis should be placed on cognitive as well as performance skills. If the objective or competency will be evaluated by a job sheet, it is often necessary to determine by a written test whether the student understands enough of the material to perform the job sheet.

SUGGESTED ACTIVITIES

The following list of suggested activities may be helpful, especially to the beginning instructor.

1. Provide students with objective sheet and information sheets.
2. Discuss unit and specific objectives.
3. Discuss information sheets, assignment sheets and/or job sheets, lesson-by-lesson.
4. Have students do assignment sheet(s) to satisfactory levels.
5. Give students unit test.
6. After successful completion of the test, have students do job sheet(s).

Students should perform the following activities.

1. Read objective sheet.
2. Study information sheets.
3. Do assignment sheet(s).
4. Take unit test.
5. Do job sheets.

PACKAGING

This Machine Shop guide has been packaged with the entire class in mind. For the teacher, a complete instructor's guide contains all eight modules. In the student reference, selected portions have been reproduced for student use (objectives page, information sheets, handouts). Student work sheets (assignment sheets, job sheets, unit tests) have been packaged together for student distribution as the instructor deems necessary.

In the student reference, page numbers do not run consecutively because some pages have been removed that appear only in the instructor's guide.

MODULE 2: MEASUREMENT AND BLUEPRINT READING

CROSS-REFERENCE TABLE OF INSTRUCTIONAL MATERIALS

Competency	Instructional Objective	Transparency Master	Handout	Assignment Sheet	Job Sheet	Test Item	Notes
C1	I 2.1-3.1, II 1.3		I 2.1	I 2.1	I 3.1	I 21-32, II 10	
C2	II 1.1,1.4				II 1.1	II 2	
C3	II 1.1,1.5			II 1.1,1.2	II 1.2	II 5-7	
C4	II 1.1,1.6				II 1.3	II 3,8,9	
C5	III 1.1-1.4				III 1.1-1.3	III 1-3	
C6	III 1.5			III 1.1	III 1.4	III 5	
C7	III 1.6				III 1.5	III 4	
C8	II 1.7				II 1.4	II 4	
C9	IV 1.1-1.6				IV 1.1	IV 1-11	
C10	V 2.1	V 2.2			V 2.2	V 12,16	
C11	V 1.1,1.2	V 1.1,2.1			V 1.1,2.1	V 1-13,15	
C12	IV 1.4,1.7				IV 1.2	IV 12	
C13	V 3.1,3.2				V 3.1	V 17,18	
C14	VII 1.2-1.6		VII 1.1		VII 1.1,1.2	VII 3,5-13	
C15	VI 2.2-2.4				VI 2.1		
C16	VI 2.2-2.4				VI 2.1	VI 2	
C17	VI 2.5				VI 2.2		
C18	VI 1.1,1.2	VI 1.1,1.2		VI 1.1	VI 1.1,2.2	VI 1,3,5-7	

Competency	Instructional Objective	Transparency Master	Handout	Assignment Sheet	Job Sheet	Test Item	Notes
C20	V4.1-4.3				V 4.1	V 13,14	
C21	VI 2.6				VI 2.3	VI 4	
D1	VIII 1.1-1.4, 2.1-2.4			VIII 1.1,1.2		VIII 1-25	
D2	IX 1.1-1.7					IX 1-26	
D3	IX 2.1-2.3		IX 1.1		IX 2.1		
D4	I 1.4, X 1.1,1.2		I 1.1	I 1.1, X 1.1		I 2,6,9-14,16,18,20, X 1-17	
D5	XII 1.1,1.2		XII 1.1	XII 1.1		XII 1-15	
D6	XI 1.1-1.7		XI 1.1,1.2	XI 1.1		XI 1-31	
D7	XII 2.1			XII 2.1, VI 2.2*		XII 16-33	*In Orientation & Math module
D8							Notes to Instructor
D9	VI 1.1		VI 1.1,1.2	VI 1.1,1.2		VI A1-10,B1-9	In Lathes module

MODULE: MEASUREMENT AND BLUEPRINT READING
UNIT I: INTRODUCTION TO PRECISION MEASUREMENT

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to define measurement terms, identify and describe the measuring tools, their functions and care for these tools. This knowledge will be evidenced by completion of the job sheet and unit test to a specified score.

SPECIFIC OBJECTIVES

After completion of the lessons in this unit, the student should be able to:

1.1 Match measurement terms and definitions.

1.2 Identify the types of shop measurement.

1.3 Distinguish between measurement systems.

1.4 Define and use measurement standards and fit designations. (competency D4)

2.1 Identify and describe the function of semi-precision measuring tools.

2.2 Identify and describe the function of precision measuring tools.

3.1 Care for precision instruments. (competency C1, JS 3.1)

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT I: INTRODUCTION TO PRECISION MEASUREMENT

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plans

1. Lesson 1: OVERVIEW OF SHOP MEASUREMENT
   - a. Information outline
   - b. Handout
     - HO 1.1: Geometric tolerance symbols
   - c. Assignment sheet
     - AS 1.1: Measurement terms and fit designations
   - d. Answers to assignment sheet
2. Lesson 2: MEASUREMENT TOOLS
   - a. Information outline
   - b. HO 2.1: Semi-precision measuring tools
   - c. Assignment sheet
     - AS 2.1: Identifying measuring tools and functions
   - d. Answers to assignment sheet
3. Lesson 3: HANDLING AND STORING MEASURING TOOLS
   - a. Information outline
   - b. Job sheet
     - JS 3.1: Care for precision instruments

E. Unit test

F. Answers to unit test

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REFERENCES

A. Books

1. Precision Measurement in the Metalworking Industry. Vocational Education Program for National Defense Industries. Endicott, NY: State Education Department, The University of the State of New York, March 1941.
2. Repp, Victor E., and Willard J. McCarthy. Machine Tool Technology. 5th ed. Bloomington, IL: McKnight Publishing Co., 1984.
3. Olivo, C. Thomas. Advanced Machine Tool Technology. North Scituate, MA: Breton Publishers, 1982.
4. Repp, Victor E., Willard J. McCarthy and Oswald A. Ludwig. Metalwork Technology and Practice. Bloomington, IL: McKnight Publishing Co., 1982.

NOTES TO THE INSTRUCTOR

A. Suggested supplemental materials

1. Dimensioning and Tolerancing (ANSI Y14.5M). New York: The American Society of Mechanical Engineers, 1982.
2. Precision Tools, Gages and Saws (Catalog No. 28). 1st ed. Athol, MA: The L. S. Starrett Company, 1986.
3. Oberg, Erik; Franklin D. Jones; Holbrook L. Horton. Machinery's Handbook. 23rd ed. New York: Industrial Press Inc., 1988.

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT I: INTRODUCTION TO PRECISION MEASUREMENT

LESSON 1: OVERVIEW OF SHOP MEASUREMENT

I. Terms and definitions

- A. Actual size--measured dimensions of a part
- B. Allowance--intentional difference between the upper limit of one part and the lower limit of its mating part
- C. ANSI (American National Standards Institute)--a division of the American Society of Mechanical Engineers which establishes standards for tolerancing and measurement nationwide
- D. Clearance fit--amount of space between parts which provides a space between the surface of mating parts; a sliding or running fit
- E. Fit--degree of tightness between mating parts
- F. Geometric tolerancing--system for control of part features based on ANSI Y14.5M-1982.
- G. Interchangeability of parts--characteristic of parts which have been produced using an appropriate system of dimensioning and tolerancing for control of part quality
- H. Interference fit--type of fit which provides no clearance between the surfaces of mating parts, as in a "press fit"
- I. ISO (International Standards Organization)--international group which establishes standards for science and engineering
- J. Limits--minimum and maximum sizes of a part as defined by the tolerance
- K. Tolerance--total allowable variation in a part dimension

II. Types of shop measurement (HO 1.1)

- A. Linear--measurement along a line or straight-line measurement (metric or English units)
- B. Angular--measurement of angles (usually in degrees)
- C. Geometric--measurement of part features as described in ANSI Y14.5M, 1982; takes into consideration such factors as parallelism, cylindricity, flatness, angularity, etc.

III. Measurement systems

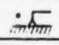
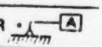
- A. The ISO metric system is accepted worldwide. The basic unit of linear measure is the meter.
- B. The English system of measurement is still commonly used in the United States.
  1. The basic unit of linear measure is the inch.
  2. Subdivisions can be fractional (1/64, 1/32, 1/16, 1/8, 1/4, 1/2) or decimal portions of the inch.

IV. Shop measurement principles

- A. Measurement standards
  - 1. Provide for interchangeability of parts
  - 2. Expression of tolerances
    - a. Plus/minus tolerancing (1.000 ± .005")
    - b. Limit tolerancing $\frac{0.995}{1.005}$
- B. Fit designation (clearance or interference)
  - 1. Fit designation is based upon the basic size of a part.
    - a. A typical application is fitting a shaft in a hole.
    - b. A decision must be made whether to apply the allowance to the shaft or the hole. This should be based upon the most economical means of producing each part.
  - 2. Tables are used to determine the upper and lower limits of the basic size of either a shaft or hole for a clearance fit. (Refer to the Machinery's Handbook or ANSI standards.)

HO 1.1

GEOMETRIC TOLERANCE SYMBOLS

SYMBOL FOR:	ANSI Y14.5	ISO
STRAIGHTNESS	⏤	⏤
FLATNESS	⏥	⏥
CIRCULARITY	○	○
CYLINDRICITY	⌭	⌭
PROFILE OF A LINE	⌒	⌒
PROFILE OF A SURFACE	⌓	⌓
ALL AROUND–PROFILE	⟵○⟶	NONE
ANGULARITY	∠	∠
PERPENDICULARITY	⊥	⊥
PARALLELISM	//	//
POSITION	⌖	⌖
CONCENTRICITY/COAXIALITY	◎	◎
SYMMETRY	NONE	⌯
CIRCULAR RUNOUT	*↗	↗
TOTAL RUNOUT	*⌰	⌰
AT MAXIMUM MATERIAL CONDITION	Ⓜ	Ⓜ
AT LEAST MATERIAL CONDITION	Ⓛ	NONE
REGARDLESS OF FEATURE SIZE	Ⓢ	NONE
PROJECTED TOLERANCE ZONE	Ⓟ	Ⓟ
DIAMETER	Ø	Ø
BASIC DIMENSION	[50]	[50]
REFERENCE DIMENSION	(50)	(50)
DATUM FEATURE	[-A-]	 OR 
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TARGET POINT	×	×

*MAY BE FILLED IN

Credit: Dimensioning and Tolerancing (ANSI Y14.5M). New York: The American Society of Mechanical Engineers, 1982.

MEASUREMENT TERMS AND FIT DESIGNATIONS

Define each term listed.

1. Actual size
2. Allowance
3. ANSI
4. Clearance fit
5. Fit
6. Geometric tolerancing
7. Interchangeability of parts
8. Interference fit
9. ISO
10. Limits
11. Tolerance

Use the chart to answer the following questions.

Nominal Size Range, Inches	Class RC1			Class RC2			Class RC3			Class RC4		
	Clearance*	Standard Tolerance Limits		Clearance*	Standard Tolerance Limits		Clearance*	Standard Tolerance Limits		Clearance*	Standard Tolerance Limits	
		Hole H5	Shaft g4		Hole H6	Shaft g5		Hole H7	Shaft f6		Hole H8	Shaft f7
Over To	Values shown below are in thousandths of an inch											
0–0.12	0.1 0.45	+0.2 0	−0.1 −0.25	0.1 0.55	+0.25 0	−0.1 −0.3	0.3 0.95	+0.4 0	−0.3 −0.55	0.3 1.3	+0.6 0	−0.3 −0.7
0.12–0.24	0.15 0.5	+0.2 0	−0.15 −0.3	0.15 0.65	+0.3 0	−0.15 −0.35	0.4 1.12	+0.5 0	−0.4 −0.7	0.4 1.6	+0.7 0	−0.4 −0.9
0.24–0.40	0.2 0.6	+0.25 0	−0.2 −0.35	0.2 0.85	+0.4 0	−0.2 −0.45	0.5 1.5	+0.6 0	−0.5 −0.9	0.5 2.0	+0.9 0	−0.5 −1.1
0.40–0.71	0.25 0.75	+0.3 0	−0.25 −0.45	0.25 0.95	+0.4 0	−0.25 −0.55	0.6 1.7	+0.7 0	−0.6 −1.0	0.6 2.3	+1.0 0	−0.6 −1.3
0.71–1.19	0.3 0.95	+0.4 0	−0.3 −0.55	0.3 1.2	+0.5 0	−0.3 −0.7	0.8 2.1	+0.8 0	−0.8 −1.3	0.8 2.8	+1.2 0	−0.8 −1.6
1.19–1.97	0.4 1.1	+0.4 0	−0.4 −0.7	0.4 1.4	+0.6 0	−0.4 −0.8	1.0 2.6	+1.0 0	−1.0 −1.6	1.0 3.6	+1.6 0	−1.0 −2.0
1.97–3.15	0.4 1.2	+0.5 0	−0.4 −0.7	0.4 1.6	+0.7 0	−0.4 −0.9	1.2 3.1	+1.2 0	−1.2 −1.9	1.2 4.2	+1.8 0	−1.2 −2.4
3.15–4.73	0.5 1.5	+0.6 0	−0.5 −0.9	0.5 2.0	+0.9 0	−0.5 −1.1	1.4 3.7	+1.4 0	−1.4 −2.3	1.4 5.0	+2.2 0	−1.4 −2.8
4.73–7.09	0.6 1.8	+0.7 0	−0.6 −1.1	0.6 2.3	+1.0 0	−0.6 −1.3	1.6 4.2	+1.6 0	−1.6 −2.6	1.6 5.7	+2.5 0	−1.6 −3.2
7.09–9.85	0.6 2.0	+0.8 0	−0.6 −1.2	0.6 2.6	+1.2 0	−0.6 −1.4	2.0 5.0	+1.8 0	−2.0 −3.2	2.0 6.6	+2.8 0	−2.0 −3.8
9.85–12.41	0.8 2.3	+0.9 0	−0.8 −1.4	0.8 2.9	+1.2 0	−0.8 −1.7	2.5 5.7	+2.0 0	−2.5 −3.7	2.5 7.5	+3.0 0	−2.5 −4.5
12.41–15.75	1.0 2.7	+1.0 0	−1.0 −1.7	1.0 3.4	+1.4 0	−1.0 −2.0	3.0 6.6	+2.2 0	−3.0 −4.4	3.0 8.7	+3.5 0	−3.0 −5.2
15.75–19.69	1.2 3.0	+1.0 0	−1.2 −2.0	1.2 3.8	+1.6 0	−1.2 −2.2	4.0 8.1	+2.5 0	−4.0 −5.6	4.0 10.5	+4.0 0	−4.0 −6.5

Credit: ANSI B4.1-1967 (revised 1974). Used with permission. For larger diameters, see the standard.

12. Describe the upper and lower limits of the hole for a class RC-3 fit of a shaft with a basic dimension of 1.000" (basic shaft system).

13. What allowance could be applied to the shaft for an RC 2 fit in the basic hole system if the hole diameter is 5.000"?

ANSWERS TO AS 1.1

1. Actual size--measured dimensions of a part
2. Allowance--intentional difference between the upper limit of one part and the lower limit of its mating part
3. ANSI (American National Standards Institute)--a division of the American Society of Mechanical Engineers which establishes standards for tolerancing and measurement nationwide
4. Clearance fit--amount of space between parts which provides a space between the surface of mating parts; a sliding or running fit
5. Fit--degree of tightness between mating parts
6. Geometric tolerancing--system for control of part features based on ANSI Y14.5M-1982.
7. Interchangeability of parts--characteristic of parts which have been produced using an appropriate system of dimensioning and tolerancing for control of part quality
8. Interference fit--type of fit which provides no clearance between the surfaces of mating parts, as in a "press fit"
9. ISO (International Standards Organization)--international group which establishes standards for science and engineering
10. Limits--minimum and maximum sizes of a part as defined by the tolerance
11. Tolerance--total allowable variation in a part dimension
12. 1.000-1.008
13. .0007"

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT I: INTRODUCTION TO PRECISION MEASUREMENT

LESSON 2: MEASUREMENT TOOLS

I. Semi-precision measuring tools (HO 2.1)

   A. Tape measure--linear measuring device available in lengths of 6-100'

   B. Pocket rule--small, convenient rule

   C. Bench rule--standard 12" rule usually graduated in both fractional and decimal-inch equivalents

   D. Slide caliper--semi-precision caliper used to size round stock or take inside measurements

   E. Combination set--versatile measuring and layout tool consisting of blade/rule, square head, protractor head and center head

   F. Dividers--compass-like devices used for the layout of circles and arcs and for the measurement of lines and circles by division

   G. Hermaphrodite calipers--devices similar to dividers except that one leg is long and curved to slide along the edge of the work (particularly adapted to producing parallel lines)

   H. Spring calipers--inside and outside types; semi-precision, indirect measuring tool

II. Precision measuring tools

   A. Vernier caliper--precision linear measurement tool with a movable, auxiliary scale which subdivides graduations on the main scale

   B. Dial caliper--precision linear measurement tool with a graduated circular plate (dial)

   C. Depth micrometer--device used to measure hole depths to the nearest 0.001" (0.05 mm)

   D. Outside micrometer caliper--device used to measure a shaft diameter, part thickness and other linear dimensions to the nearest 0.001" (0.05 mm)

   E. Inside micrometer--device used to measure linear dimensions between parts or hole diameters to the nearest 0.001" (0.05 mm)

   F. Telescope gage--indirect measuring device used with an outside micrometer caliper to measure hole diameters

   G. Small hole gage--indirect measuring device used with an outside micrometer caliper to measure hole diameters (especially those under 0.250" or 7 mm)

   H. Plug and ring gages--special instruments used to quickly check the diameter of shafts (ring gage) or holes (plug gage) in a high production setting

   I. Height gage--special instrument used with a surface plate to measure or layout workpieces with extreme accuracy

J. Surface plate--precision ground and polished plate made of cast iron or granite which is used as a primary datum or reference surface for measurement, inspection and layout to a close tolerance

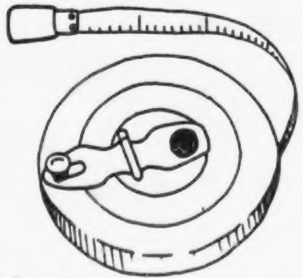
K. Gage blocks--set of extremely accurate blocks of various thicknesses which are used in the machine shop as master gages for calibration and setting of other measuring instruments (also known as Johansson or "Jo" blocks)

L. Dial indicator--device with a watch-like movement and dial face used to measure, inspect and set-up workpieces on a surface plate or directly in the machine tool

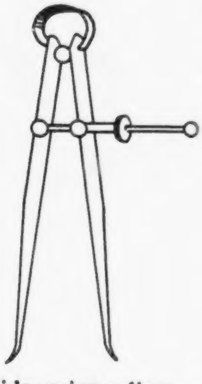
M. Thread wire--set of accurately machined wire. When used with an outside micrometer caliper, it can be used to determine the depth of a thread's cut.

N. Sine bar--highly accurate, hardened-steel bar with two attached cylinders which have centers located a known distance from each other (usually 5"). The sine bar is used with gage blocks to inspect angles machined on workpieces.

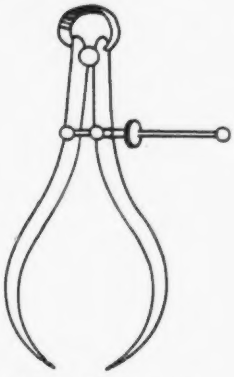
SEMI-PRECISION MEASURING TOOLS



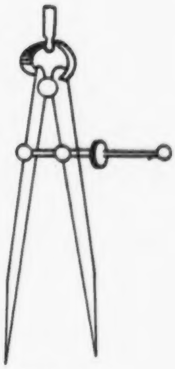
Steel tape



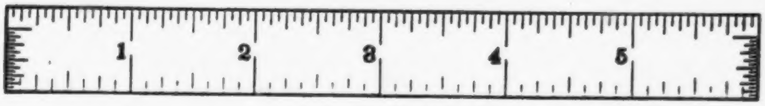
Inside spring caliper



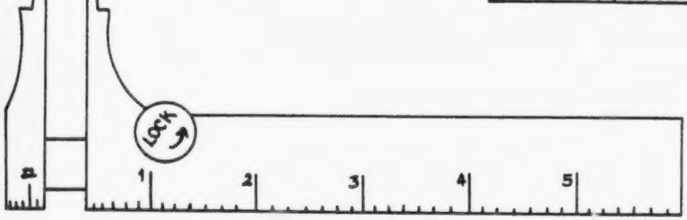
Outside spring caliper



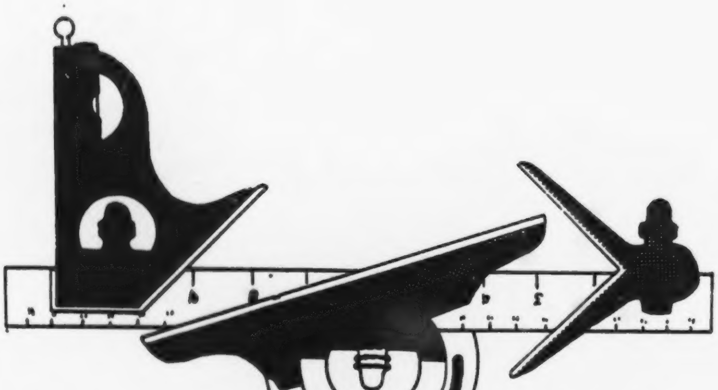
Divider



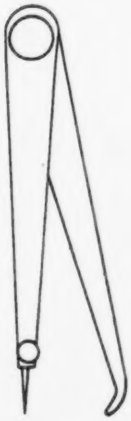
Pocket rule



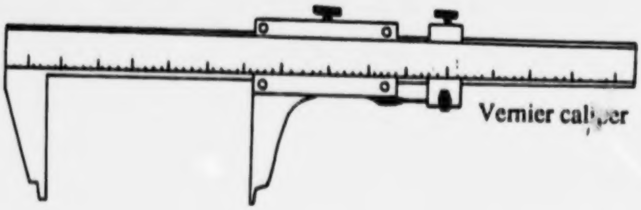
Slide caliper

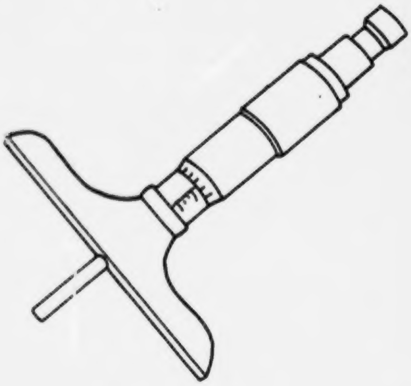


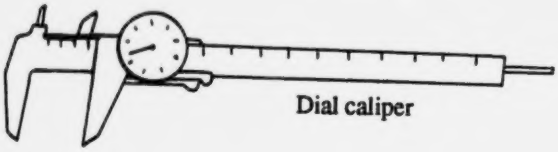
Combination set

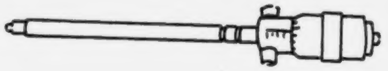


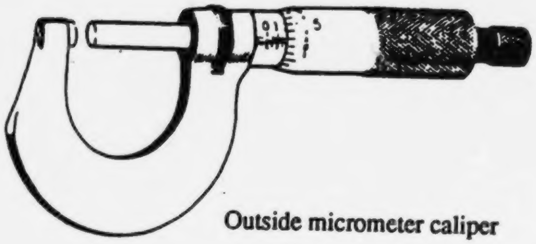
Hermaphrodite caliper

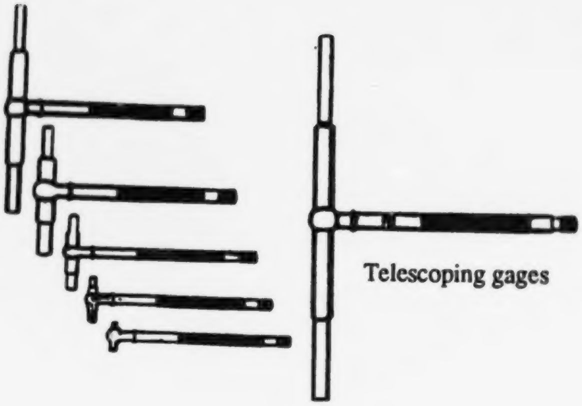

Vernier caliper

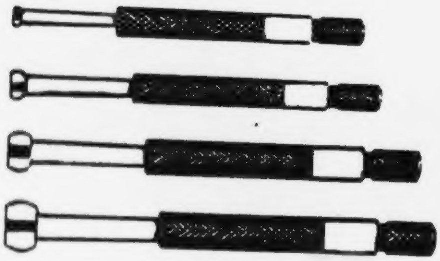

Depth micrometer

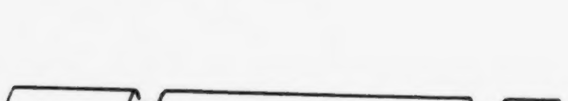

Dial caliper

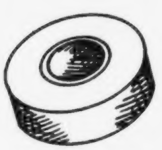

Inside micrometer

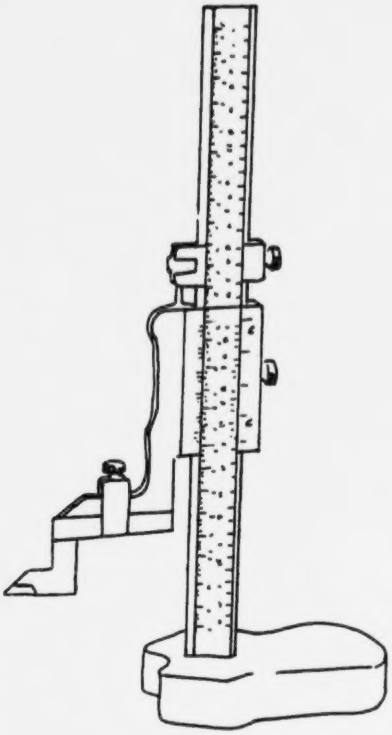

Outside micrometer caliper


Telescoping gages

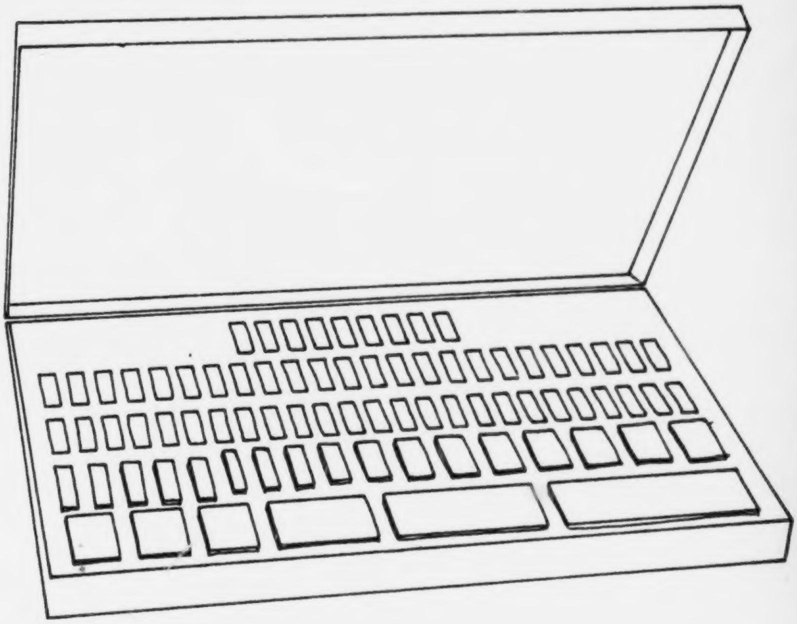

Small hole gages


Plug gage

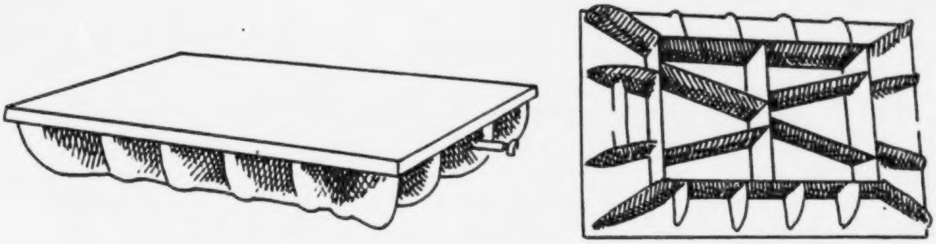

Ring gage



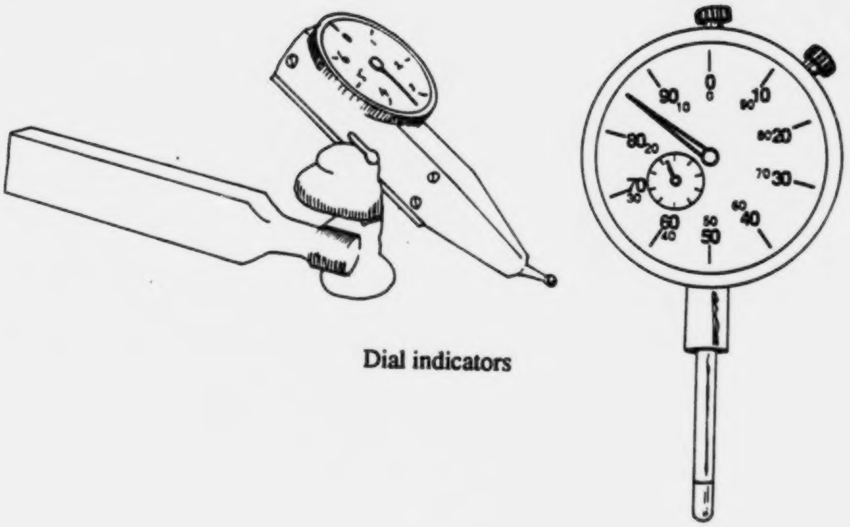
Height gage



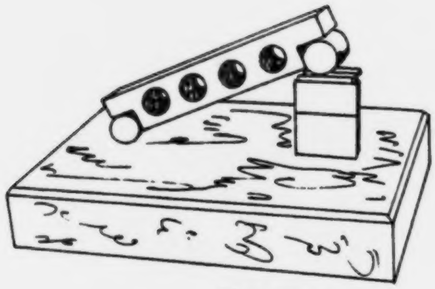
Set of gage blocks



Surface plate



Dial indicators



Sine bar set

IDENTIFYING MEASURING TOOLS AND FUNCTIONS

Match tools to their functions.

____ 1. Semi-precision instrument used to size round stock or take inside measurements

____ 2. Versatile measuring and layout tool consisting of blade/rule, square head, protractor head and center head

____ 3. Compass-like devices used for the layout of circles and arcs and for the measurement of lines and circles

____ 4. Compass-like device with one leg long and curved to slide along the edge of the work (particularly adapted to producing parallel lines)

____ 5. Precision linear measurement tool with a movable, auxiliary scale

____ 6. Used to measure a shaft diameter, part thickness and other linear dimensions to the nearest 0.001"

____ 7. Used to measure linear dimensions between parts or hole diameters to the nearest 0.001"

____ 8. Indirect measuring device used with an outside micrometer caliper to measure hole diameters

____ 9. Indirect measuring device used with an outside micrometer caliper to measure hole diameters (especially those under 0.250" or 7 mm)

____ 10. Special instruments used to quickly check the diameter of shafts or holes in a high production setting

____ 11. Special instrument used with a surface plate to measure or layout workpieces with extreme accuracy

____ 12. Set of extremely accurate pieces of various thicknesses used as master gages for calibration (also known as "Jo" blocks)

____ 13. Device with a watch-like movement and dial face used to measure, inspect and set-up workpieces on a surface plate or directly in the machine tool

a. Combination set

b. Depth micrometer

c. Dial caliper

d. Dial indicator

e. Dividers

ab. Gage blocks

ac. Height gage

ad. Hermaphrodite calipers

ae. Inside micrometer

bc. Outside micrometer caliper

bd. Plug or ring gage

be. Slide caliper

cd. Small hole gage

ce. Telescope gage

de. Vernier caliper

ANSWERS TO AS 2.1

1. be
2. a
3. e
4. ad
5. de
6. bc
7. ae
8. ce
9. cd
10. bd
11. ac
12. ab
13. d

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT I: INTRODUCTION TO PRECISION MEASUREMENT

LESSON 3: HANDLING AND STORING MEASURING TOOLS

I. Care of precision measuring tools

  A. Handling

    1. Use precision measuring tools only for their intended purposes.
    2. The surfaces must be protected.
    3. Do not allow measuring tools to knock together.
    4. Always place a shop towel on the machine table before putting down the tool. This will protect both the measuring tool and the machine table.

  B. Storage

    1. Store in a cool, dry place.
    2. Store in the original box or case whenever possible.
    3. Do not store measuring tools loose in a toolbox.

  C. Maintenance and lubrication

    1. Clean tools with a soft cloth after use and before storing.
    2. Oil moving parts and exposed surfaces with small amount of sewing machine oil or other light oil to maintain the tool in proper working condition and prevent corrosion.

JS 3.1

CARE FOR PRECISION INSTRUMENTS

Equipment:

Various precision measuring tools
Clean shop towels
Sewing machine or other suitable multipurpose oil

Procedure:	Evaluation 3	 2	 1	 N
1. With shop towels, cover an area of the workbench large enough to contain the tools which will be examined.	___	___	___	___
2. Remove the measuring tools from storage and carefully place them on the shop towels. Do not allow the tools to touch.	___	___	___	___
3. Identify joints and moving parts. Lubricate these with one or two drops of sewing machine oil. As directed by the instructor, disassemble micrometers to lubricate the screw of each one.	___	___	___	___
4. Apply a few drops of oil to a clean shop towel; use the towel to wipe each tool before placing it back in its case.	___	___	___	___
5. Return all tools to proper storage areas.	___	___	___	___
Average of above evaluations*	___	___	___	___

*This average is the student's final evaluation for competency C1: Care for precision instruments.

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT I: INTRODUCTION TO PRECISION MEASUREMENT

UNIT TEST

Match terms with definitions.

____ 1. A fit which has no clearance between the surfaces of mating parts

____ 2. Total allowable variation in a part dimension

____ 3. Degree of tightness between mating parts

____ 4. Measured size of a part

____ 5. Intentional difference between the upper limit of one part and the lower limit of its mate

____ 6. Tolerancing system for control of features based on ANSI Y14.5M

____ 7. Fit which provides a measure of clearance between the surface of mating parts

____ 8. Minimum and maximum sizes of a part defined by the tolerance

a. Actual size
b. Allowance
c. Clearance fit
d. Fit
e. Geometric tolerancing
ab. Interference fit
ac. Limits
ad. Tolerance

Match each geometric tolerance feature listed below with the correct symbol.

____ 9. Flatness

____ 10. Angularity

____ 11. Diameter

____ 12. Perpendicularity

____ 13. Straightness

____ 14. Cylindricity

a. ⏤
b. ⏥
c. ⌭
d. ∠
e. ⊥
ab. ⌀
ac. ⌓

Select the option which answers the question or completes the statement.

____ 15. The most widely accepted measurement system in the world is the __________ system.

a. Imperial
b. Metric
c. Inch
d. English
e. None of the above

____ 16. The limits of a part with a tolerance of 1.000 ±0.005 are __________ .

a. 1.000 to 1.110
b. 0.005 to 0.010
c. 0.021 to 0.098
d. 0.995 to 1.005
e. None of the above

____ 17. Measurement along a line is known as ____________ .

a. A linear measurement
b. An angular measurement
c. Flatness
d. Perpendicularity
e. None of the above

____ 18. The tolerance, 1.000 ±0.005, is commonly called ____________ .

a. Limit dimensioning
b. Plus/minus tolerancing
c. Overall tolerance
d. Allowance
e. None of the above

____ 19. Interchangeability of parts means that ________________ .

a. Parts produced to the same standard of measurement will be interchangeable worldwide
b. All parts must be produced to the closest possible tolerance
c. Metric and inch parts will interchange
d. Limit tolerancing must be used
e. None of the above

____ 20. In the basic hole system, the allowance is applied to the ______ .

a. Drill
b. Shaft
c. Hole
d. Machine tool
e. None of the above

____ 21. Which of the following is not an appropriate practice for precision measuring tools?

a. Oil lightly
b. Wipe clean before putting away
c. Wash with a mild detergent
d. Place on a shop towel to protect from damage
e. All of the above

____ 22. Which type of gage is an indirect measuring device used with an outside micrometer caliper to measure hole diameters (especially those under 0.250" or 7 mm)?

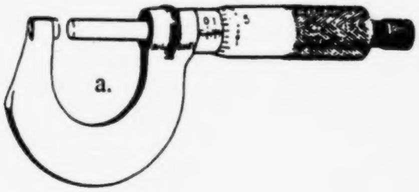
a. Telescope gage
b. Small hole gage
c. Plug or ring gages
d. Height gage
e. None of the above

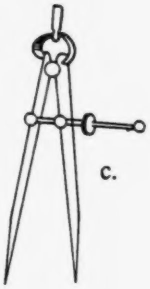
____ 23. An outside micrometer caliper measures to the nearest _________ .

a. 0.01"
b. 0.005"
c. 0.001"
d. 0.0005"
e. 0.0001"

Match the tool names with the illustrations.

____ 24. Pocket rule
____ 25. Depth micrometer
____ 26. Combination set
____ 27. Small hole gages
____ 28. Outside micrometer caliper
____ 29. Hermaphrodite caliper
____ 30. Dividers
____ 31. Inside spring calipers
____ 32. Telescoping gage


a.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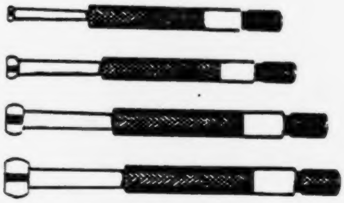
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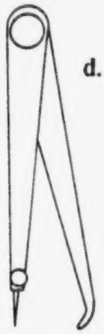
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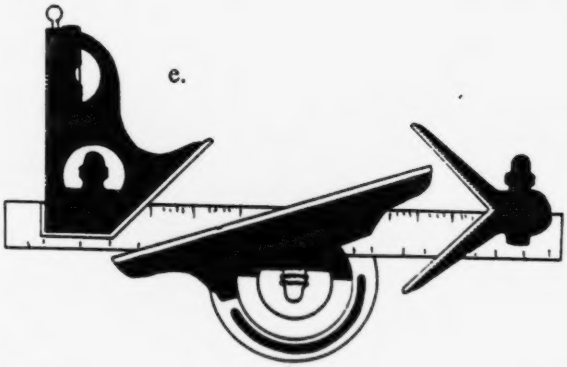
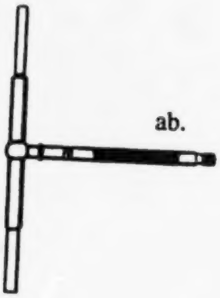
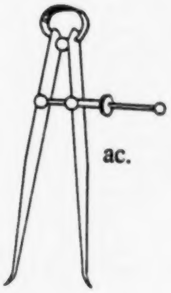
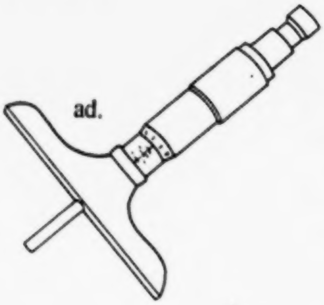
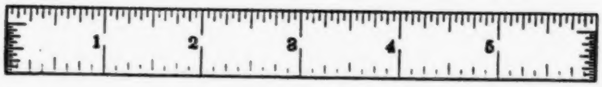

e.


ab.


ac.


ad.



ae.

NOTE: Completion of this unit test to specified score is the student's partial evaluation for competency C1: Care for precision instruments.

ANSWERS TO UNIT TEST (C1)

1.	ab	
2.	ad	(D4)
3.	d	
4.	a	
5.	b	
6.	e	(D4)
7.	c	
8.	ac	
9.	b	(D4)
10.	d	(D4)
11.	ab	(D4)
12.	e	(D4)
13.	a	(D4)
14.	c	(D4)
15.	b	(D4)
16.	d	(D4)
17.	a	
18.	b	(D4)
19.	a	
20.	b	(D4)
21.	c	(C1)
22.	b	(C1)
23.	c	(C1)
24.	ae	(C1)
25.	ad	(C1)
26.	e	(C1)
27.	b	(C1)
28.	a	(C1)
29.	d	(C1)
30.	c	(C1)
31.	ac	(C1)
32.	ab	(C1)

MODULE: MEASUREMENT AND BLUEPRINT READING
UNIT II: SEMI-PRECISION LINEAR MEASUREMENT

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to perform semi-precision measurements using tape measures, rules and calipers. This knowledge will be evidenced by achieving a specified score on job sheets and the unit test.

SPECIFIC OBJECTIVES

After completion of the lesson in this unit, the student should be able to:

1.1 Identify and describe direct-reading semi-precision measuring tools.

1.2 Identify and describe indirect-reading semi-precision measuring tools.

1.3 Identify care techniques for precision measuring tools. (competency C1)

1.4 Measure workpiece with tape measure. (competency C2, JS 1.1)

1.5 Measure workpiece with pocket rule. (competency C3, JS 1.2)

1.6 Measure workpiece with slide caliper rule. (competency C4, JS 1.3)

1.7 Measure workpiece with spring calipers. (competency C8, JS 1.4)

MODULE: MEASUREMENT AND BLUEPRINT READING
UNIT II: SEMI-PRECISION LINEAR MEASUREMENT

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to perform semi-precision measurements using tape measures, rules and calipers. This knowledge will be evidenced by achieving a specified score on job sheets and the unit test.

SPECIFIC OBJECTIVES

After completion of the lesson in this unit, the student should be able to:

1.1 Identify and describe direct-reading semi-precision measuring tools.

1.2 Identify and describe indirect-reading semi-precision measuring tools.

1.3 Identify care techniques for precision measuring tools. (competency C1)

1.4 Measure workpiece with tape measure. (competency C2, JS 1.1)

1.5 Measure workpiece with pocket rule. (competency C3, JS 1.2)

1.6 Measure workpiece with slide caliper rule. (competency C4, JS 1.3)

1.7 Measure workpiece with spring calipers. (competency C8, JS 1.4)

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT II: SEMI-PRECISION LINEAR MEASUREMENT

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plan

  1. Lesson 1: SEMI-PRECISION LINEAR-MEASUREMENT TOOLS

    a. Information outline

    b. Assignment sheets

      AS 1.1: Fractional measurement with a bench rule
      AS 1.2: Metric measurement with a bench rule

    c. Job sheets

      JS 1.1: Measure workpiece with tape measure
      JS 1.2: Measure workpiece with pocket rule
      JS 1.3: Measure workpiece with slide caliper rule
      JS 1.4: Measure workpiece with spring calipers

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. Precision Measurement in the Metalworking Industry. Vocational Education Program for National Defense Industries. Endicott, NY: State Education Department, The University of the State of New York, March 1941.

2. Olivo, C. Thomas. Machine Tool Technology and Manufacturing Processes. Albany, NY: C. Thomas Olivo Associates, 1987.

3. Repp, Victor E., and Willard J. McCarthy. Machine Tool Technology. 5th ed. Bloomington, IL: McKnight Publishing Co., 1984.

4. Repp, Victor E., Willard J. McCarthy and Oswald A. Ludwig. Metalwork Technology and Practice. Bloomington, IL: McKnight Publishing Co., 1982.

NOTES TO THE INSTRUCTOR

A. Suggested supplemental materials

1. Semi-Precision Measuring Devices (MS-86-302) (video). Sedalia, MO: State Fair Community College, 1986. (Available for purchase from SFCC; available for loan from Missouri Vocational Resource Center, phone 800/392-7217 or 314/882-9610)

2. Precision Tools, Gages and Saws (Catalog No. 28). 1st ed. Athol, MA: The L. S. Starrett Company, 1986.

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MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT II: SEMI-PRECISION LINEAR MEASUREMENT

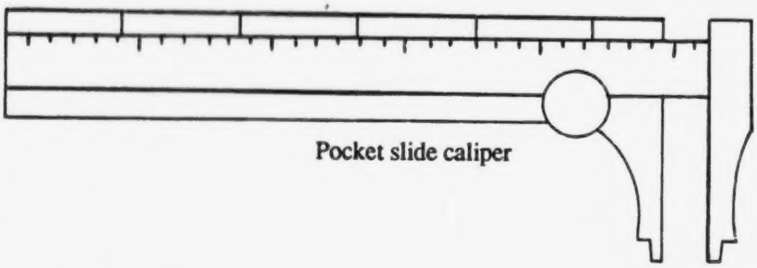
LESSON 1: SEMI-PRECISION LINEAR-MEASUREMENT TOOLS

I. Direct-reading semi-precision measuring tools

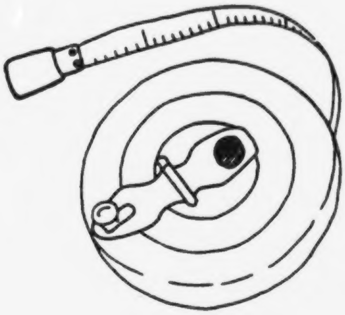
NOTE: Part tolerances determine whether to use semi-precision or precision measuring tools. It is neither economical nor sensible to measure work to within 0.001" when a fractional dimension has been specified.

A. Semi-precision line-graduated linear-measurement tools

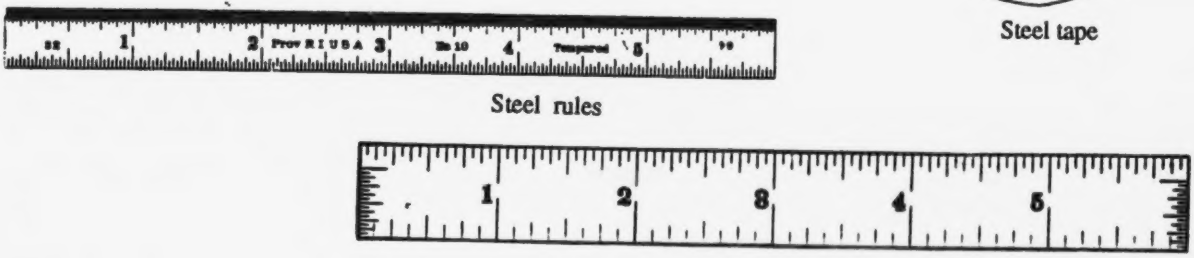
1. Tape measure
    - a. Metric or inch
    - b. Available in sizes of 6'-100'
2. The bench rule and pocket rule are convenient for general-purpose measuring.
    - a. The pocket rule, generally 6" long, has a clip.
    - b. Bench rules are usually 12" in length.
    - c. Measurement units include fractional inches (to 1/64), decimal inches (to 0.01) and metric (to 1/2 mm).
3. The slide caliper is useful for quickly determining the diameter of a material piece, especially when selecting materials from storage.



Pocket slide caliper



Steel tape



Steel rules

II. Indirect-reading semi-precision tools or spring calipers

NOTE: Spring calipers can be used for very close measurements even though there are no gradations. Since there is a considerable amount of "feel" involved, experience is needed for reliable measurements.

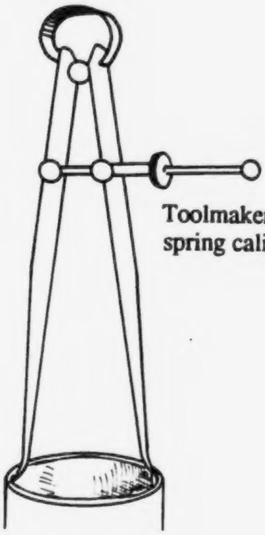
A. Types

1. Outside spring caliper are used for outside dimensions.
2. Inside spring calipers are used for inside dimensions.

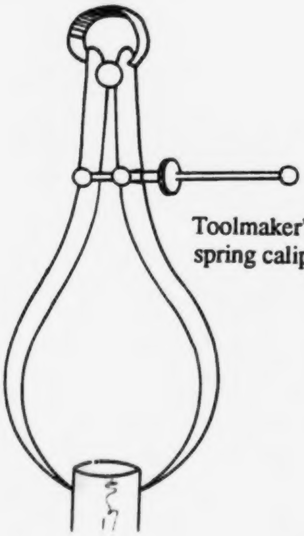
B. Techniques for use

1. Measure the work and compare the leg spread with the rule measurement.
2. Set the legs with the rule and compare with the workpiece.

NOTE: This measurement can be more closely defined by using precision measuring tools.



Toolmaker's inside spring caliper



Toolmaker's outside spring caliper

III. Care of semi-precision measuring tools

A. Keep tools clean and dry.

B. Store in original boxes or in a manner which will protect them from scratches or other damage.

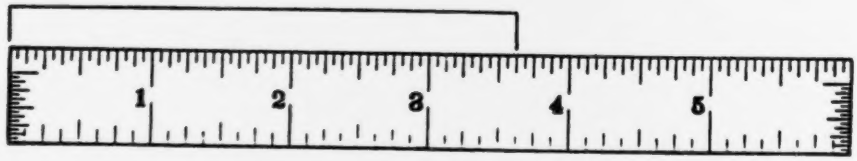
C. Oil lightly to prevent corrosion.

FRACTIONAL MEASUREMENT WITH A BENCH RULE

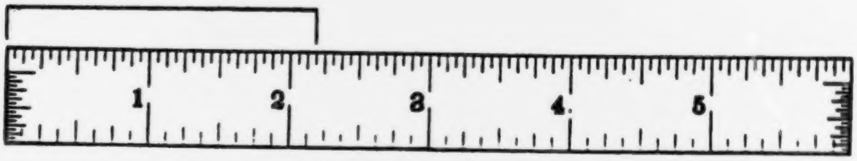
Identify the measurements shown below by selecting the appropriate answer.

a. 7/16"
b. 2 3/16"
c. 2 3/4"
d. 3 5/8"
e. 4 1/4"
ab. 4 15/16"

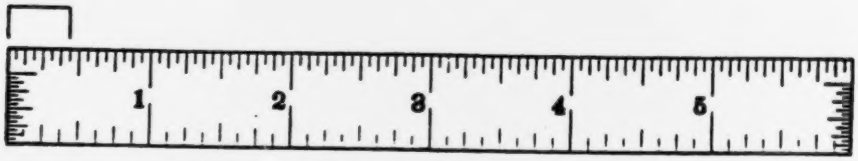
___ 1.



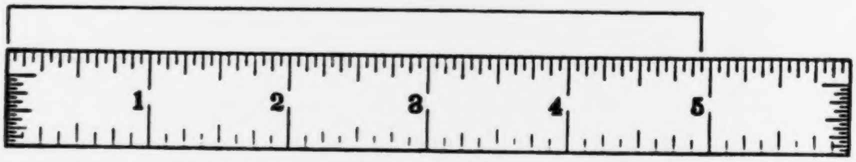
___ 2.



___ 3.



___ 4.



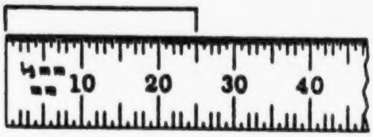
AS 1.2

METRIC MEASUREMENT WITH A BENCH RULE

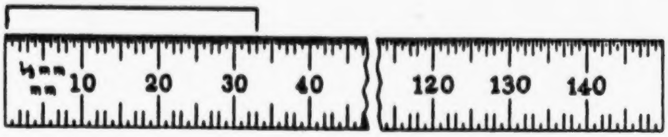
Identify the measurements shown below by selecting the appropriate answer.

a. 25 mm
b. 33 mm
c. 33.5 mm
d. 41 mm
e. 65 mm
ab. 123 mm

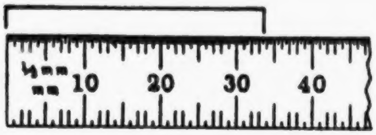
___ 1.



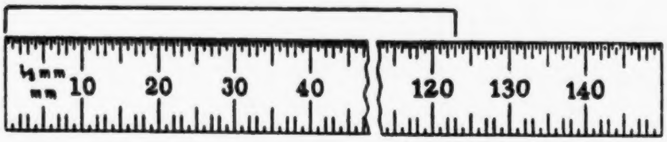
___ 2.



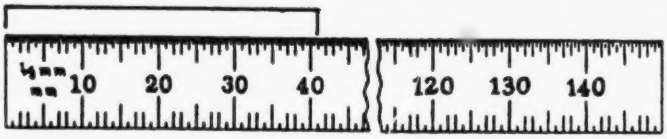
___ 3.



___ 4.



___ 5.



ANSWERS TO AS 1.1

1. d
2. b
3. a
4. ab

ANSWERS TO AS 1.2

1. a
2. b
3. c
4. ab
5. d

JS 1.1

MEASURE WORKPIECE WITH TAPE MEASURE

Equipment:

50' or 100' tape measure
Quad-graduated drawing paper
Pencil or pen

NOTE: This job sheet is best completed by two students working together.

Procedure:

Evaluation
3 2 1 N

1. Obtain the equipment listed above. Make a list of all of the major equipment and machines in the shop.
2. Measure the dimensions of the shop floor and do a sketch of this layout. Use a scale which is appropriate for the size of your paper.
3. Measure and note the "footprint" of each machine that was listed in the first step.
4. Measure the location of each machine; chart these locations on your floor plan.
5. Ask instructor to evaluate recorded measurements.* — — — —
6. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials.

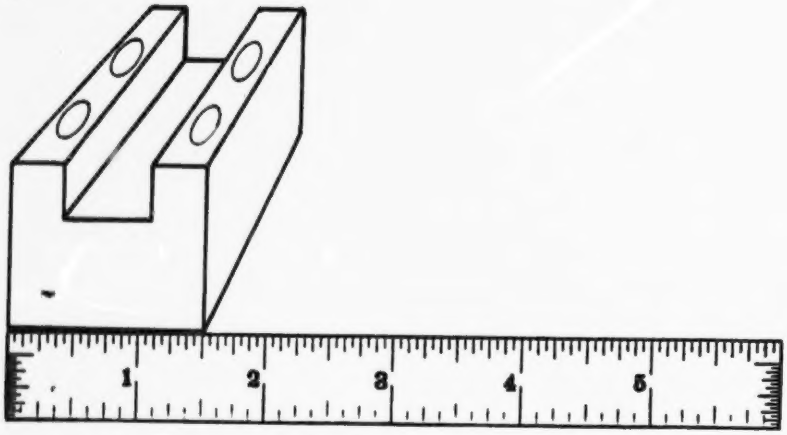
*This average is the student's final evaluation for competency C2: Measure workpiece with tape measure.

JS 1.2

MEASURE WORKPIECE WITH POCKET RULE

Equipment:

Small machine part with simple features (holes, slots, etc.)
Pocket rule
Paper and pencil



Procedure:

Evaluation
3 2 1 N

1. Obtain the equipment listed. Measure the part and record the dimensions of the part features to within ± 1/64". — — — —

2. Create a sketch of the part to scale. — — — —

3. Ask instructor to check your measurements and sketch. — — — —

4. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials.

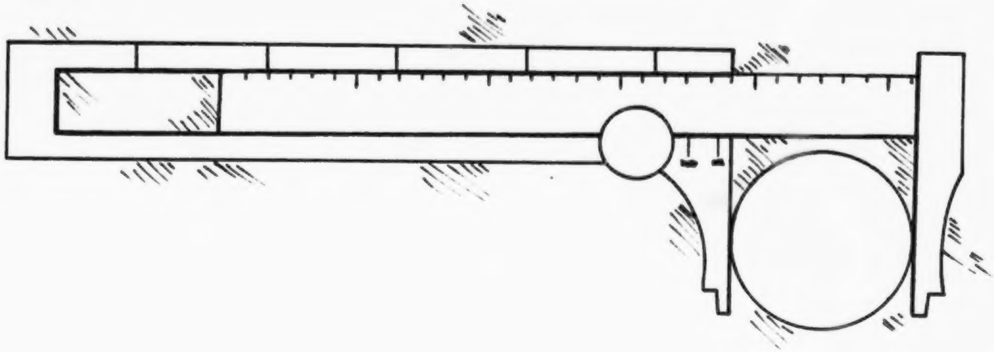
Average of above evaluations* — — — —

*This average is the student's final evaluation for competency C3: Measure workpiece with pocket rule.

MEASURE WORKPIECE WITH SLIDE CALIPER RULE

Equipment:

Slide caliper
Various sizes of round stock (1/2-2" in diameter and up to 4" in length)



Procedure:

Evaluation
3 2 1 N

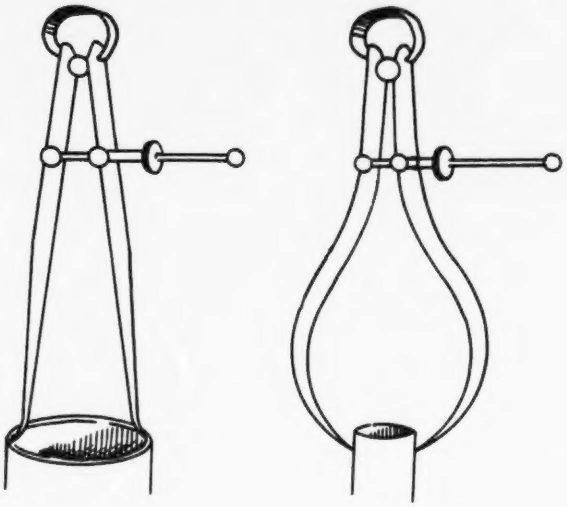
1. Obtain the equipment listed. Measure and record the diameter and length of each piece of stock to within ±1/64".
2. Compare measurements with instructor's.* — — — —
3. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials.

*This evaluation is the student's final evaluation for competency C4: Measure workpiece with slide caliper rule.

MEASURE WORKPIECE WITH SPRING CALIPERS

Equipment:

6" inside spring caliper
6" outside spring caliper
12" bench rule
Assortment of short pieces of pipe of various diameters



Procedure:

Evaluation
3 2 1 N

1. Obtain the equipment listed. Measure and record the inside stock diameter with the inside spring caliper and the outside stock diameter with the outside spring caliper.

   NOTE: Measurements must be transferable from the caliper to the bench rule to within ±1/64". This measurement can be more closely defined by using precision measurement tools.

2. Check measurements against the instructor's.* — — — —

3. Clean up area and return tools and materials.

*This evaluation is the student's final evaluation for competency C8: Measure workpiece with spring calipers.

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT II: SEMI-PRECISION LINEAR MEASUREMENT

UNIT TEST

Select the option which answers the question or completes the statement.

____ 1. In determining whether to use semi-precision measuring tools, what factor must be considered?

a. Overall length of the part
b. Part tolerances
c. Available calibration devices
d. Total number of flat surfaces
e. None of the above

____ 2. Which tool listed below is best for layout of a shop floor?

a. Spring caliper
b. Dividers
c. Bench rule
d. Tape measure
e. None of the above

____ 3. Which device listed below would be best for measuring the diameter or thickness of stock in a metal storage rack?

a. Slide calipers
b. Pocket rule
c. Outside spring caliper
d. Tape measure
e. None of the above

____ 4. Which would be a good combination of tools for measuring the inside diameter of a pipe?

a. Inside spring caliper and bench rule
b. Tape measure and pocket rule
c. Outside and inside spring calipers
d. Tape measure and outside spring caliper
e. None of the above

____ 5. What is the smallest graduation usually found on a metric bench rule?

a. .001 mm
b. .001 inch
c. .5 mm
d. 10 mm
e. None of the above

____ 6. English bench rules are graduated in ________ .

a. Decimal
b. Fractional
c. Metric
d. Decimal and fractional
e. None of the above

____ 7. What is the smallest fractional dimension indicated on an English bench rule?

a. 1/8
b. 1/16
c. 1/32
d. 1/64
e. 1/128

____ 8. What is the most important factor in using a spring caliper?

a. The accuracy of the part
b. Experience
c. Reading the graduation properly
d. Slide caliper settings
e. None of the above

____ 9. Which tool is useful for quickly determining the diameter of round stock?

a. Bench rule
b. Slide caliper
c. Tape measure
d. Inside caliper
e. None of the above

____ 10. Which of the following is not a consideration in the proper care of semi-precision measuring tools?

a. Re-calibrate them often
b. Store in their original containers
c. Keep them dry
d. Keep them clean
e. Oil lightly to inhibit corrosion

ANSWERS TO UNIT TEST

1.	b	
2.	d	(C2)
3.	a	(C4)
4.	a	(C8)
5.	c	(C3)
6.	d	(C3)
7.	d	(C3)
8.	b	(C4)
9.	b	(C4)
10.	a	(C1)

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT III: SIMPLE LAYOUT TECHNIQUES

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to use combination sets, dividers and hermaphrodite calipers to lay out part features. This knowledge will be evidenced by achieving a specified score on job sheets and the unit test.

SPECIFIC OBJECTIVES

After completion of the lesson in this unit, the student should be able to:

1.1 Describe the use of precision layout tools.

1.2 Lay out hole centers with a combination square. (competency C5, JS 1.1)

1.3 Locate and mark the center of round stock. (competency C5, JS 1.2)

1.4 Lay out angles with a combination-set protractor head. (competency C5, JS 1.3)

1.5 Transfer measurement with dividers. (competency C6, JS 1.4)

1.6 Lay out workpiece with hermaphrodite calipers. (competency C7, JS 1.5)

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT III: SIMPLE LAYOUT TECHNIQUES

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plan

1. Lesson 1: LAYOUT TOOLS AND METHODS
   - a. Information outline
   - b. Assignment sheet
     - AS 1.1: Calculating the spread of wing-divider legs
   - c. Job sheets
     - JS 1.1: Lay out hole centers with a combination square
     - JS 1.2: Locate and mark the center of round stock
     - JS 1.3: Lay out angles with a combination-set protractor head
     - JS 1.4: Transfer measurement with dividers
     - JS 1.5: Lay out workpiece with hermaphrodite calipers

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. Precision Measurement in the Metalworking Industry. Vocational Education Program for National Defense Industries. Endicott, NY: State Education Department, The University of the State of New York, March 1941.

2. Olivo, C. Thomas. Advanced Machine Tool Technology. North Scituate, MA: Breton Publishers, 1982.

3. Repp, Victor E., and Willard J. McCarthy. Machine Tool Technology. 5th ed. Bloomington, IL: McKnight Publishing Co., 1984.

4. Repp, Victor E., Willard J. McCarthy and Oswald A. Ludwig. Metalwork Technology and Practice. Bloomington, IL: McKnight Publishing Co., 1982.

NOTES TO THE INSTRUCTOR

A. Suggested supplemental materials

1. Identification and Use of Basic Layout Tools (MS-84-300) (video). Sedalia, MO: State Fair Community College, 1984. (Available for purchase from SFCC; available for loan from Missouri Vocational Resource Center, phone 800/392-7217 or 314/882-9610)

2. Precision Tools, Gages and Saws (Catalog No. 28). 1st ed. Athol, MA: The L. S. Starrett Company, 1986.

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT III: SIMPLE LAYOUT TECHNIQUES

LESSON 1: LAYOUT TOOLS AND METHODS

I. Tools for semi-precision layout

A. Combination set

1. Blade

2. Square head

a. Scriber

b. Bubble level

3. Center head

4. Protractor head

B. Wing dividers

C. Hermaphrodite calipers

D. Layout fluid (usually blue)

E. Scriber

F. Punches

1. Prick punch

2. Center punch

G. Machinist's (ball-peen) hammers are available in various weights, such as 4 oz., 8 oz., 12 oz. and 16 oz.

II. Layout techniques

A. The combination set is an extremely versatile layout and measurement tool.

1. The blade, a graduated bench rule, has a slot to accept a pin which holds the other parts in place.

2. The square head is used alone or with the blade.

a. It can be used to test squareness or layout 90° or 45° lines.

b. It has a bubble level for checking surface levelness and a convenient built-in scriber.

3. The center head is used with the blade to test and scribe 45° angles and to locate and mark the center of cylindrical ends.

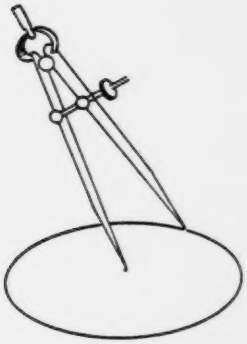
4. The protractor head is used alone or with the blade to test and layout all angles of 0-180° to within 0.5°.

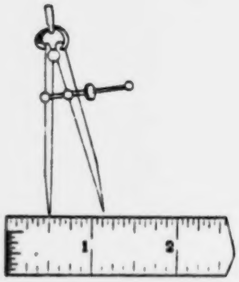
B. Wing dividers are used to "divide" a line into equal parts and to scribe arcs and circles.

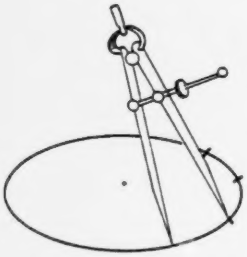
1. Excellent for layout of bolt hole patterns

2. Requires trigonometry to calculate the length of the chord which becomes the width setting of the divider legs

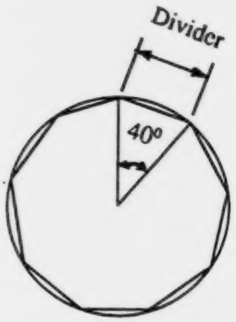
Example: Setting the divider to lay out nine equally spaced holes on a 6" diameter bolt circle





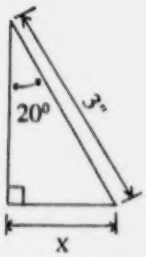


a.



b. Bisecting the 40° angle creates two 20° right triangles.

c.



Sin 20° = $\frac{x}{3}$

d. Sin 20° = .3420

e. .3420 = $\frac{x}{3}$

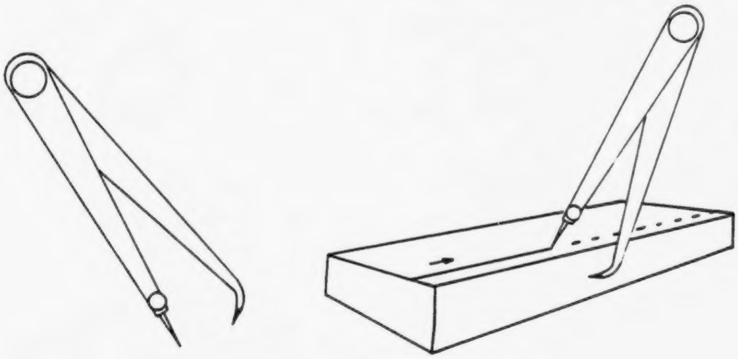
f. $(3)\ .3420 = \frac{x}{3}\,(3)$

$1.026 = x$

g. Divider setting = 2 (1.026)

h. Divider setting = 2.052

C. Hermaphrodite calipers are used to lay out lines parallel to an edge.



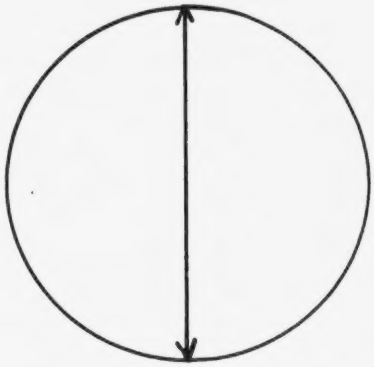
1. Set the distance from the point of one leg to the inside of the hooked surface on the other leg.
2. While scribing the workpiece, hook the leg on the edge of the work and slide slowly along the length of the edge.

AS 1.1

CALCULATING THE SPREAD OF WING-DIVIDER LEGS

It is often necessary to lay out equally spaced holes around a circle. In the example below, lay out five holes on a 10" diameter circle. Calculate the divider setting for laying out the five hole centers on the bolt circle. Show all work.

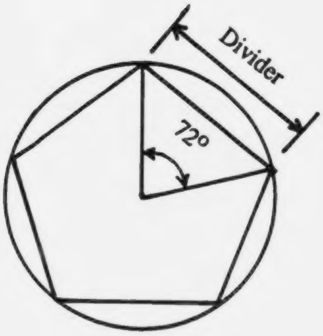
$$\text{Sine} = \frac{\text{opposite}}{\text{hypotenuse}}$$



10" bolt circle

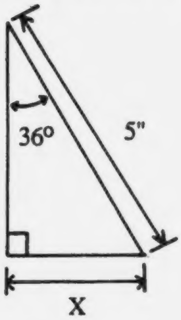
ANSWERS TO AS 1.1

1.



2. Bisecting the 72° angle creates two 36° right triangles.

3.



$\text{Sin } 36° = \frac{x}{5}$

4. $\text{Sin } 36° = .5878$

5. $.5878 = \frac{x}{5}$

6. $(5)\ .5878 = \frac{x}{5}\ (5)$

$2.939 = x$

7. Divider setting = 2 (2.939)

8. Divider setting = 5.878

JS 1.1

LAY OUT HOLE CENTERS WITH A COMBINATION SQUARE

Equipment:

Combination set (blade and square head)
Scriber
Layout blue
Workpiece
Prick and center punches
Ball-peen hammer

	Evaluation			
Procedure:	3	2	1	N
1. Coat the workpiece face (on which the centers are to be marked) with layout dye.	___	___	___	___
2. Identify two reference surfaces on the part. These surfaces will be used to assure measurement accuracy and squareness of the layout lines.	___	___	___	___
3. Hole location requires measurement from both reference surfaces (or two coordinates). Measure from the corner formed by the two reference edges in each direction for each hole location using the combination set blade or a bench rule. Mark each measurement by scribing a "tick" mark on the edge of the workpiece.	___	___	___	___
4. Assemble the blade and square head. Lay the square against the edge of the work with the blade aligned with a tick mark and extending across the workpiece. Scribe a line across the work using the blade as a guide for the scriber. Repeat with all tick marks. The work surface now has a set of crossed lines.	___	___	___	___
5. Using the prick punch and a machinist's hammer, carefully locate and place light indentations at each intersection. Feel this intersection mark with the center punch and deepen the mark by striking the end of the punch.	___	___	___	___
6. Check the work with the combination set. The hole center positions should be located to within ± 1/64".	___	___	___	___
7. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials.	___	___	___	___
Average of above evaluations*	___	___	___	___

*This average is the student's partial evaluation for competency C5: Lay out work with combination square.

JS 1.2

LOCATE AND MARK THE CENTER OF ROUND STOCK

Equipment:

Combination set (blade and center head)
Scriber
Layout blue
Workpiece (round stock)
Drawing of hole layout
Bench vise
Prick and center punches
Ball-peen hammer

Procedure:	Evaluation 3	 2	 1	 N
1. Coat the workpiece end on which the center is to be located with layout dye.	___	___	___	___
2. Mount the workpiece vertically in the vise. Assemble the center head and the blade.	___	___	___	___
3. Place the center head across the end of the work as illustrated. Scribe a line across the work using the edge of the blade as a guide.	___	___	___	___
4. Turn the blade and center head to 90° of the scribed line. Mark another line intersecting the first line. This intersection is the center of the workpiece.	___	___	___	___
5. Mark the end with a prick and center punch.	___	___	___	___
6. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials.	___	___	___	___
Average of above evaluations*	___	___	___	___

*This average is the student's partial evaluation for competency C5: Lay out work with combination square.

LAY OUT ANGLES WITH A COMBINATION-SET PROTRACTOR HEAD

Equipment:

Combination set (blade and protractor head)
Scriber
Layout blue
Workpiece
Drawing of line layout
Prick and center punches
Ball-peen hammer

Procedure:	Evaluation 3	 2	 1	 N
1. Coat the workpiece face on which the line is to be marked with layout dye.	—	—	—	—
2. Identify the reference surfaces from which the angles will be measured and marked.	—	—	—	—
3. Measure from the corner intersection of the reference edges and place a tick mark where the angle will start.	—	—	—	—
4. Set the protractor for the first angle. Place the edge of the protractor head against the reference surface with the blade extending across the workpiece. Using the blade as a guide, mark the angle with a scriber.	—	—	—	—
5. Set the protractor for the second angle. Repeat as above. Angular lines must be drawn to within ± 1°.	—	—	—	—
6. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials.	—	—	—	—
Average of above evaluations*	—	—	—	—

*This average completes the student's evaluation for competency C5: Lay out work with combination square.

JS 1.4

TRANSFER MEASUREMENT WITH DIVIDERS

Equipment:

Wing divider
Layout blue
Bench rule
Calculator
Table of trigonometric functions
Scriber
Drawing of bolt pattern
Workpiece
Prick punch
Ball-peen hammer

Procedure:	Evaluation 3	 2	 1	 N
1. Coat the workpiece face on which the centers are to be marked with layout dye.	—	—	—	—
2. Locate the center of the bolt-hole circle. Punch the center using a prick punch and hammer. Set the wing dividers for the bolt-circle radius with a bench rule. Place one leg of the divider in the prick punch mark and scribe the bolt circle with the other leg.	—	—	—	—
3. Calculate the extension of the wing-divider legs.	—	—	—	—
4. Set wing-divider spread with the bench rule to obtain equal hole spacing as specified on the part drawing.	—	—	—	—
5. Identify the start for the first bolt-hole center. Scribe an intersection across the bolt-hole circle at this point. Place one leg of the divider on this point and swing the other leg across the bolt circle, scribing an arc intersection.	—	—	—	—
6. Locate the scribing leg at this new intersection and swing the other leg around; locate the third bolt-hole center by scribing another arc intersection. Repeat around the circle. The final intersection should exactly match the original scribed line.	—	—	—	—
7. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials.	—	—	—	—
Average of above evaluations*	—	—	—	—

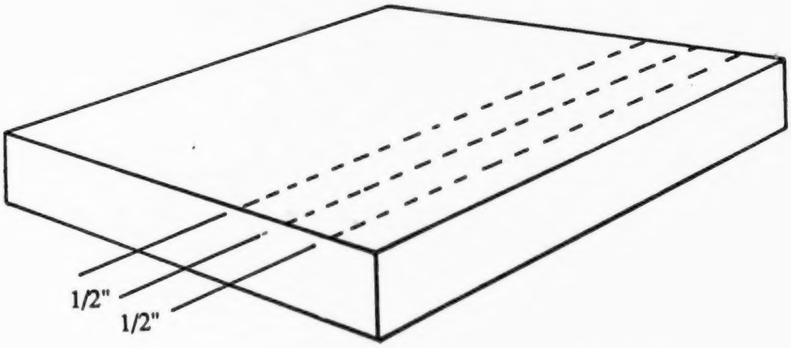
*This average is the student's final evaluation for competency C6: Transfer measurement with dividers.

JS 1:5

LAY OUT WORKPIECE WITH HERMAPHRODITE CALIPERS

Equipment:

Hermaphrodite caliper
Layout dye
Bench rule



Procedure:	Evaluation 3	 2	 1	 N
1. Coat the workpiece face on which lines are to be marked with layout dye.	—	—	—	—
2. Identify the reference surface from which parallel lines will be scribed.	—	—	—	—
3. Set the caliper spread to a distance equal from the reference edge to the line, as indicated on the part drawing.	—	—	—	—
4. Place the hooked leg of the caliper against the edge of the work and slide the scribe leg along the work.	—	—	—	—
5. Repeat for the remaining lines. The lines must be located to within ±1/64" of the dimensions specified on the part drawing.	—	—	—	—
Average of above evaluations*	—	—	—	—

*This average is the student's final evaluation for competency C7: Lay out workpiece with hermaphrodite calipers.

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT III: SIMPLE LAYOUT TECHNIQUES

UNIT TEST

Select the option which best answers the question or completes the statement.

____ 1. Which combination set component would be best for checking 90° and 45° angles?

a. Center head
b. Blade
c. Square head
d. Protractor head
e. None of the above

____ 2. Which component of a combination set would be used to check or lay out angles other than 90° or 45°?

a. Center head
b. Blade
c. Square head
d. Protractor head
e. None of the above

____ 3. Which component of a combination set would be used to locate centers on the end of round stock?

a. Center head
b. Blade
c. Square head
d. Protractor head
e. None of the above

____ 4. Which tool is best for layout of a line parallel to an edge?

a. Wing divider
b. Hermaphrodite caliper
c. Protractor head
d. Blade
e. None of the above

____ 5. Calculate the spread of wing dividers for layout of a bolt hole pattern of 10 equally spaced holes on a diameter of 10" (Sin 5° = 0.08715). The answer is __________ .

a. 0.08715
b. 5/10
c. 0.436
d. 0.872
e. None of the above

ANSWERS TO UNIT TEST

1. c (C5)
2. d (C5)
3. a (C5)
4. b (C7)
5. d (C6)

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT IV: MEASURING WITH VERNIER AND DIAL CALIPERS

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to describe and use vernier and dial calipers.

SPECIFIC OBJECTIVES

After completion of the lessons in this unit, the student should be able to:

1.1 Describe a vernier caliper.

1.2 Describe caliper measurement techniques.

1.3 Describe other vernier measuring tools.

1.4 Describe the difference between vernier and dial calipers.

1.5 Measure workpiece with vernier calipers. (competency C9, JS 1.1)

1.6 Measure workpiece with dial calipers. (competency C12, JS 1.2)

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT IV: MEASURING WITH VERNIER AND DIAL CALIPERS

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plans

1. Lesson 1: VERNIER AND DIAL CALIPERS
    a. Information outline
    b. Job sheet
        JS 1.1: Measure dimensions with a vernier caliper
        JS 1.2: Measure dimensions with a dial caliper

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. *Precision Measurement in the Metalworking Industry*. Vocational Education Program for National Defense Industries. Endicott, NY: State Education Department, The University of the State of New York, March 1941.
2. Olivo, C. Thomas. *Advanced Machine Tool Technology*. North Scituate, MA: Breton Publishers, 1982.
3. Repp, Victor E., and Willard J. McCarthy. *Machine Tool Technology*. 5th ed. Bloomington, IL: McKnight Publishing Co., 1984.
4. Repp, Victor E., Willard J. McCarthy and Oswald A. Ludwig. *Metalwork Technology and Practice*. Bloomington, IL: McKnight Publishing Co., 1982.

NOTES TO THE INSTRUCTOR

A. Suggested supplemental materials

1. *Precision Tools, Gages and Saws* (Catalog No. 28). 1st ed. Athol, Mass.: The L. S. Starrett Company, 1986.

MODULE: MEASUREMENT AND BLUEPRINT READING

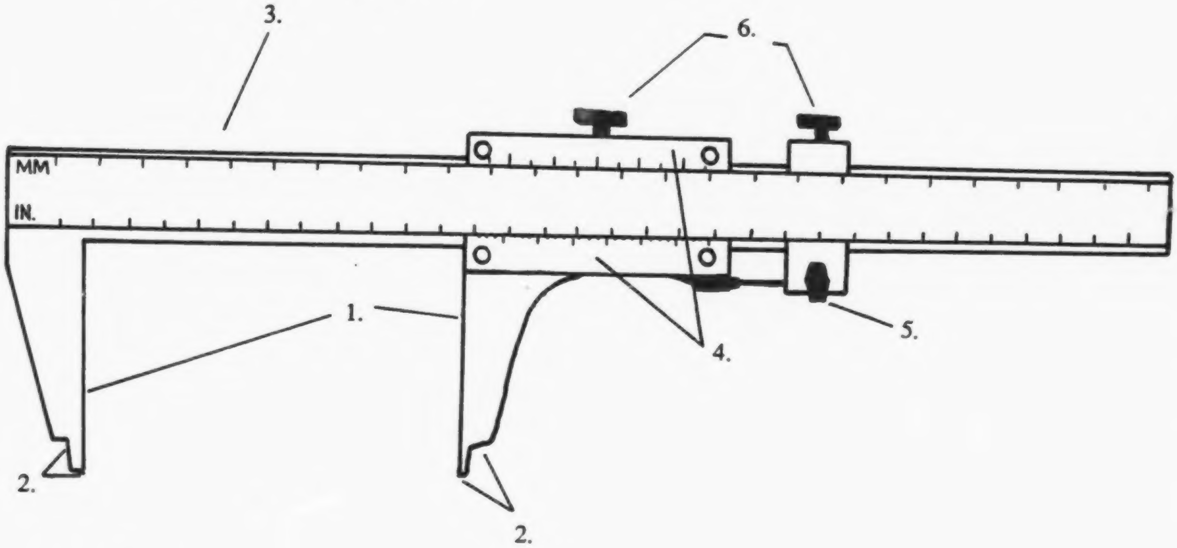
UNIT IV: MEASURING WITH VERNIER AND DIAL CALIPERS

LESSON 1: VERNIER AND DIAL CALIPERS

I. Description of vernier caliper

  A. Parts

    1. Jaws for outside measurement
    2. Nibs for inside measurement
    3. Graduated bar or beam
    4. Vernier plates (inch or metric)
    5. Fine adjustment screw
    6. Clamp or locking screws



  B. Uses

    1. Precision measurements
      a. Measures to 0.001" in English system
      b. Measures to 0.05 mm or 0.02 mm in metric system
    2. Inside or outside measurements
    3. Uses vernier scale

II. Vernier caliper techniques

NOTE: Effective use requires care and proper "feel".

A. Move the slide assembly along the beam until the work is almost contacted.

B. Lock the fine adjustment clamp screw.

C. Bring the jaws into contact with the work with the fine adjustment screw. (Don't make the contact too tight.)

D. Remove the caliper from the work and take a reading.

1. Metric

a. 0.05 mm vernier has 20 divisions.

b. 0.02 mm vernier has 50 divisions.

2. English

a. Graduated to read 0.001"

b. A 25-division vernier

c. A 50-division vernier

E. Contact the work again. Note the main beam reading.

1. This reading will be aligned with the zero on the vernier scale.

2. Graduations

a. Metric (millimeters)

b. English (40ths or 20ths of an inch)

F. Read vernier.

1. Look for the graduation on the vernier scale which is most closely aligned with any graduation on the beam.

2. Note this reading and add to the main beam reading to obtain the total measurement.

III. Other vernier measuring tools

A. Vernier height gage

B. Vernier gear tooth caliper

C. Vernier depth gage

D. Vernier protractor

IV. The dial caliper is very similar to a vernier caliper.

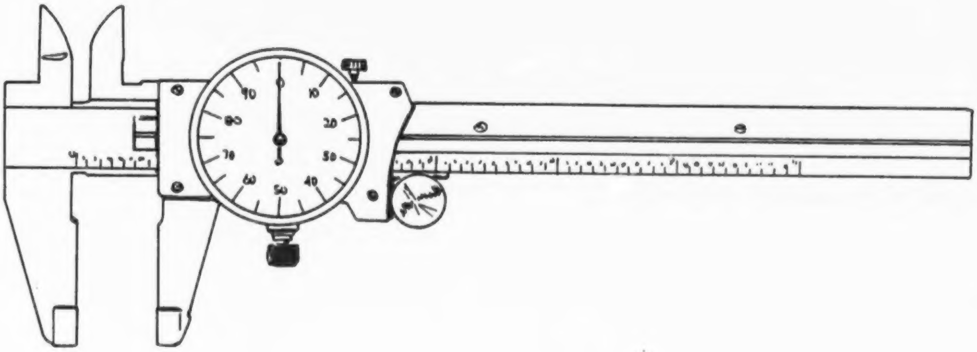
A. The vernier scale is replaced with a dial.

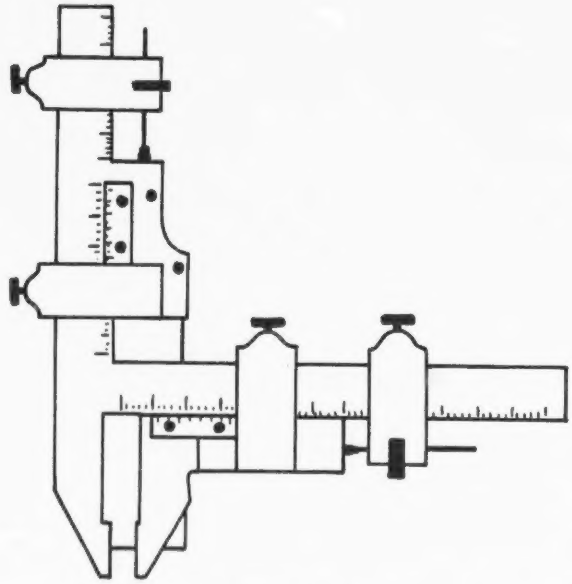
B. Measurements can be either metric or English.

C. The same techniques are used for adjustment and taking measurements as for a vernier caliper.

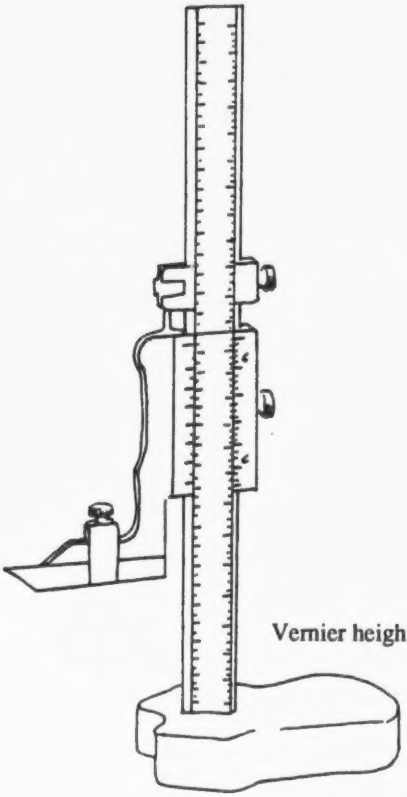
D. It is easier to read since the measurement is taken directly from the dial.

E. It is usually equipped with a roller to slide the jaws into place.

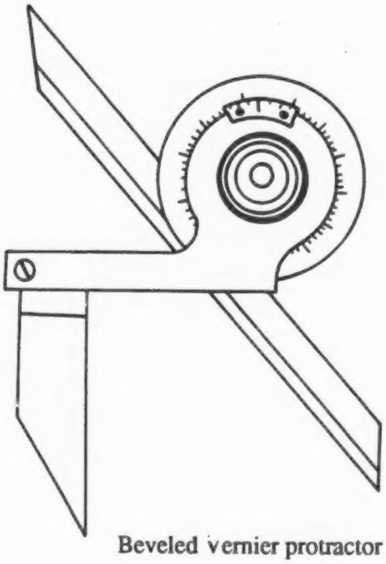




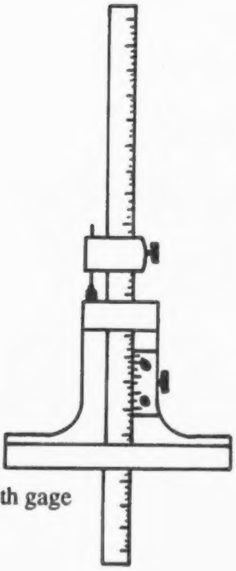
Vernier gear tooth caliper



Vernier height gage



Beveled vernier protractor



Vernier depth gage

JS 1.1

MEASURE DIMENSIONS WITH A VERNIER CALIPER

Equipment:

Vernier caliper (metric or English)
At least four workpieces (samples to include a bar, block, round stock and pipe)

Procedure:	Evaluation 3	 2	 1	 N
1. Obtain stock and caliper from instructor.	___	___	___	___
2. Measure and record specified dimensions for the bar.	___	___	___	___
3. Measure and record specified dimensions for the block.	___	___	___	___
4. Measure and record specified dimensions for the round stock.	___	___	___	___
5. Measure and record specified dimensions for the pipe. Compare each recorded measurement with the instructor's calculations.	___	___	___	___
6. Return materials; properly store caliper.	___	___	___	___
Average of above evaluations*	___	___	___	___

*This average is the student's final evaluation for competency C9: Measure workpiece with vernier calipers.

JS 1.2

MEASURE DIMENSIONS WITH A DIAL CALIPER

Equipment:

Dial caliper (metric or English)
At least four workpieces (samples to include a bar, block, round stock and pipe)

Procedure:	Evaluation 3	2	1	N
1. Obtain stock and caliper from instructor.	—	—	—	—
2. Measure and record specified dimensions for the bar.	—	—	—	—
3. Measure and record specified dimensions for the block.	—	—	—	—
4. Measure and record specified dimensions for the round stock.	—	—	—	—
5. Measure and record specified dimensions for the pipe. Compare each recorded measurement with the instructor's calculations.	—	—	—	—
6. Return materials; properly store caliper.	—	—	—	—
Average of above evaluations*	—	—	—	—

*This average is the student's final evaluation for competency C12: Measure workpiece with dial calipers.

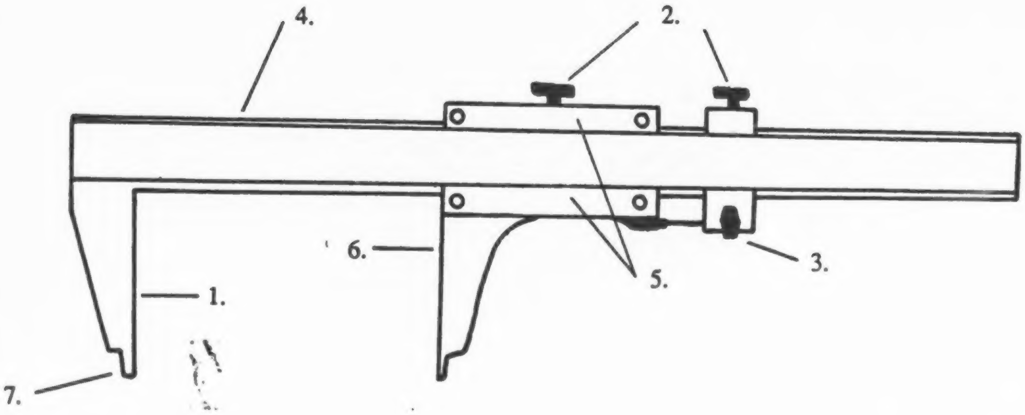
MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT IV: MEASURING WITH VERNIER AND DIAL CALIPERS

UNIT TEST

Identify the parts of the vernier caliper.

a. Vernier plate assembly
b. Nib for inside measurement
c. Moveable jaw
d. Fixed jaw
e. Fine adjustment nut
ab. Clamping screws
ac. Graduated bar or beam



____ 1.
____ 2.
____ 3.
____ 4.
____ 5.
____ 6.
____ 7.

Select the option which best answers the question or completes the statement.

____ 8. Which of the following is not a use for a vernier caliper?

a. Precision measurement
b. Inside measurement
c. Outside measurement
d. Angular measurement
e. None of the above

____ 9. What is the smallest dimension which can be measured with an inch vernier caliper?

a. 1.0000
b. 0.1000
c. 0.0100
d. 0.0010
e. 0.0001

____ 10. What is the smallest dimension that a 20-division metric vernier caliper will measure?

a. 0.01 mm
b. 0.02 mm
c. 0.05 mm
d. 0.10 mm
e. None of the above

____ 11. Besides calipers, which of the following tools could have a vernier scale?

a. Depth gage
b. Outside spring caliper
c. Telescoping gage
d. Bench rule
e. None of the above

Short answer

12. What are two ways in which a dial caliper differs from a vernier caliper?

a.

b.

ANSWERS TO UNIT TEST

1. d (C9)
2. ab (C9)
3. e (C9)
4. ac (C9)
5. a (C9)
6. c (C9)
7. b (C9)
8. d (C9)
9. d (C9)
10. c (C9)
11. a (C9)
12. Two of the following: (C12)
    a. Dial instead of vernier scale
    b. Easier to read
    c. Usually equipped with a roller to slide jaws into place

MODULE: MEASUREMENT AND BLUEPRINT READING
UNIT V: MEASURING WITH MICROMETERS

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to read and calibrate inch and metric micrometer calipers. The student should also be able to measure workpieces with depth, telescope and hole gages; micrometers; and thread wires.

SPECIFIC OBJECTIVES

After completion of the lessons in this unit, the student should be able to:

1.1 Describe outside micrometer calipers.

1.2 Measure with and calibrate outside micrometer calipers. (competency C11, JS 1.1 and 2.1)

2.1 Measure workpiece with depth gages. (competency C10, JS 2.2)

3.1 Measure workpiece with telescoping-hole gages. (competency C13, JS 3.1)

3.2 Measure workpiece with hole gages. (competency C13, JS 3.1)

4.1 Identify the techniques of measuring threads.

4.2 Describe the three-wire method.

4.3 Measure workpiece with thread wires and micrometers. (competency C20, JS 4.1)

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT V: MEASURING WITH MICROMETERS

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plans

1. Lesson 1: OUTSIDE MICROMETER CALIPERS
    a. Information outline
    b. Transparency master
        TM 1.1: Types of micrometers
    c. Job sheet
        JS 1.1: Measure with and calibrate outside micrometer calipers
2. Lesson 2: INSIDE AND DEPTH MICROMETERS
    a. Information outline
    b. Transparency masters
        TM 2.1: Inside micrometer
        TM 2.2: Depth micrometer
    c. Job sheets
        JS 2.1: Measure workpiece with inside micrometer
        JS 2.2: Measure workpiece with depth gages
3. Lesson 3: INDIRECT MICROMETER MEASUREMENTS
    a. Information outline
    b. Job sheet
        JS 3.1: Measure workpiece with telescope and hole gages
4. Lesson 4: USING THREAD MEASURING WIRE
    a. Information outline
    b. Job sheet
        JS 4.1: Measure workpiece with thread wires and micrometers

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. Precision Measurement in the Metalworking Industry. Vocational Education Program for National Defense Industries. Endicott, NY: State Education Department, The University of the State of New York, March 1941.

2. Olivo, C. Thomas. Advanced Machine Tool Technology. North Scituate, MA: Breton Publishers, 1982.

3. Repp, Victor E., and Willard J. McCarthy. Machine Tool Technology. 5th ed. Bloomington, IL: McKnight Publishing Co., 1984.

4. Repp, Victor E., Willard J. McCarthy and Oswald A. Ludwig. Metalwork Technology and Practice. Bloomington, IL: McKnight Publishing Co., 1982.

NOTES TO THE INSTRUCTOR

A. Suggested supplemental materials

1. Precision Measuring Devices: Micrometers (MS-86-303) (video). Sedalia, MO: State Fair Community College, 1986. (Available for purchase from SFCC; available for loan from Missouri Vocational Resource Center, phone 800/392-7217 or 314/882-9610)

2. Precision Tools, Gages and Saws (Catalog No. 28). 1st ed. Athol, MA: The L. S. Starrett Company, 1986.

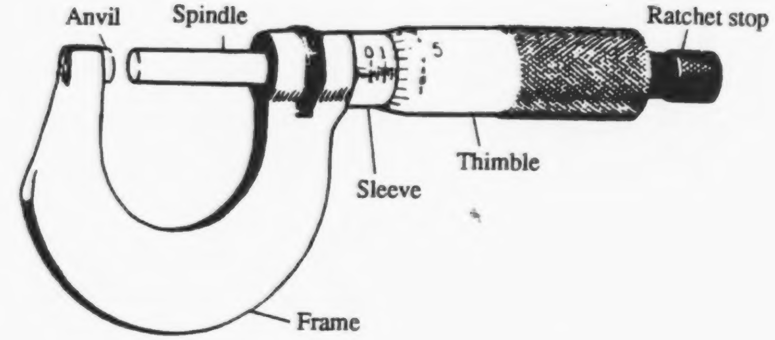
MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT V: MEASURING WITH MICROMETERS

LESSON 1: OUTSIDE MICROMETER CALIPERS

I. Description of outside micrometer calipers

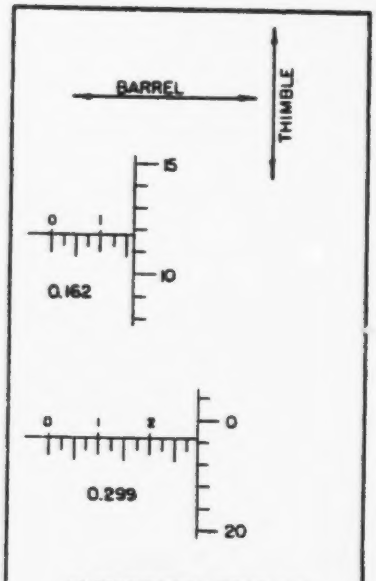
- A. Most commonly used precision measuring instrument
- B. Available in various ranges (0-25 mm or 0-1" and larger)
- C. Types **(TM 1.1)**
  - 1. Digital reading
  - 2. Plain or vernier
- D. Measurement capability
  - 1. Metric
    - a. Plain (to 0.01 mm)
    - b. Vernier (to 0.001 mm)
  - 2. Inch
    - a. Plain (to 0.001")
    - b. Vernier (to 0.0001")
- E. Major parts



II. Reading a micrometer

A. Metric

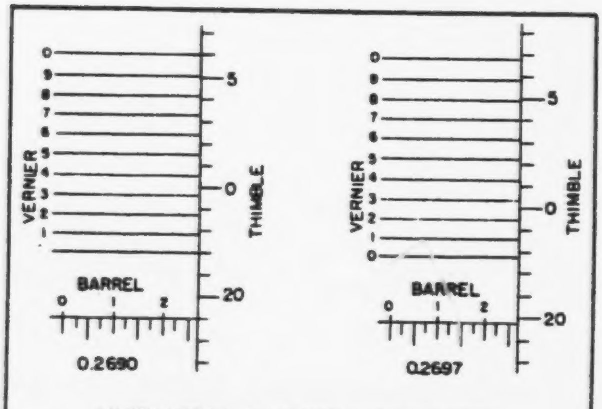
1. 50 threads per 25 mm on the screw
2. Spindle movement of 1 mm in two revolutions
3. 50 graduations on the thimble
4. Precision (0.01 mm)
5. Procedure
    a. Read the upper sleeve (whole millimeters).
    b. Read the lower sleeve (half millimeters).
    c. Read the thimble (1/100 millimeter).
    d. Read the vernier, if present.



MICROMETER READINGS

B. Inch

1. 40 threads per inch
2. Spindle movement of 1/40" or 0.025" in one revolution
3. Sleeve graduation in tenths (large division); each tenth divided into four parts (0.025" increments)
4. Procedure
    a. Read the sleeve.
    b. Read the thimble.
    c. Read the vernier, if present.



MICROMETER READINGS WITH VERNIER

III. Care and calibration

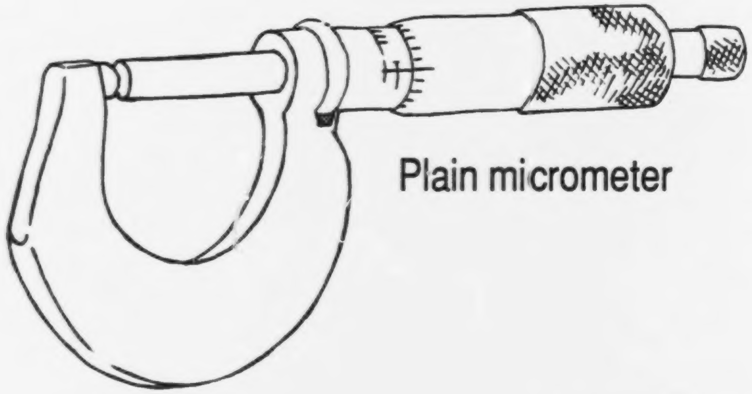
A. Care

1. Disassemble and lubricate the screw with sewing machine oil or other light lubricant.
2. Clean the face of the anvil and spindle with a lint-free cloth before each measurement.

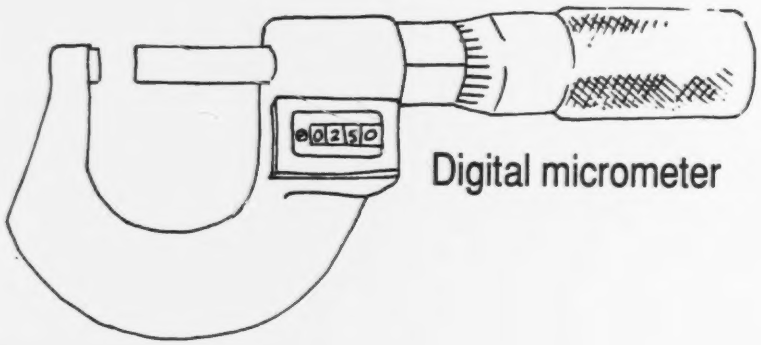
B. Calibration

1. Clean the faces of the anvil and spindle.
2. Check for end play in the screw. Tighten the nut slightly to eliminate end play, if present.
3. Use a reference standard or gage blocks of a known dimension (none required for 0-1").
4. Check the reading against the reference. Adjust to zero as needed with a spanner wrench.

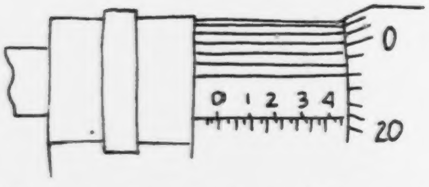
TYPES OF MICROMETERS



Plain micrometer



Digital micrometer



Micrometer scale with vernier

JS 1.1

MEASURE WITH AND CALIBRATE OUTSIDE MICROMETER CALIPERS

Equipment:

0-1" outside micrometer caliper
0-25 mm outside micrometer caliper
Spanner (provided with micrometer)
Reference standard or 1" gage block
Sewing machine oil
Clean cloth
Workpieces

Procedure:	Evaluation 3	 2	 1	 N
Calibration				
1. Disassemble micrometer and lubricate the screw with sewing machine oil or other light lubricant.	—	—	—	—
2. Reassemble the micrometer. Inspect for end play by holding the frame of the micrometer and pulling and pushing gently back and forth on the thimble.	—	—	—	—
3. Remove play, if present. Back out the screw until the adjusting nut is exposed. Place the spanner across the adjusting nut and tighten slightly (just enough to remove the play).	—	—	—	—
4. Clean the faces of the anvil and spindle with a clean, lint-free cloth. Turn thimble slowly until faces of anvil and spindle come into contact.	—	—	—	—
5. Check the reading against a reference standard or gage block (none required for 0-1" micrometer). Adjust with spanner wrench, as needed, to make the micrometer read zero.	—	—	—	—
Measurement				
6. Measure and record the workpiece dimensions with both micrometers.	—	—	—	—
7. Check the measurements against the instructor's key.	—	—	—	—
Average of above evaluations*	—	—	—	—

*This average is the student's partial (two-thirds) evaluation for competency C11: Measure workpiece with micrometers.

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT V: MEASURING WITH MICROMETERS

LESSON 2: INSIDE AND DEPTH MICROMETERS

I. Inside micrometer (used for high-precision inside measurements) **(TM 2.1)**

  A. Set contents

    1. Micrometer cylinder
    2. Extension rods
    3. Calibration spanner

  B. Techniques

    1. Effective measurement requires proper "feel".
    2. Assemble a micrometer of appropriate length.
    3. Bring the ends of the micrometer into contact with the work.
    4. Read the scale.

II. Depth micrometer (used for high-precision depth measurements) **(TM 2.2)**

  A. Set contents

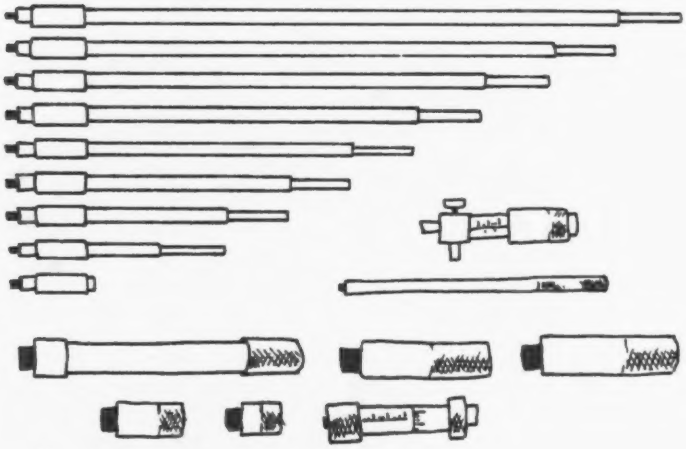
    1. Depth micrometer
    2. Extension rods
    3. Calibration spanner

  B. Techniques

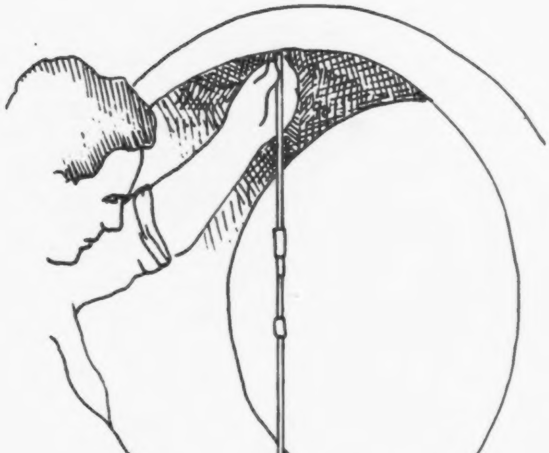
    1. Seat the base of the micrometer firmly over the feature to be gauged.
    2. Lower the tip of the micrometer into the hole or slot by turning the thimble.
    3. Read the scale.
    4. Install the necessary extension rods by unscrewing and removing the top cap; replace the rod with one of appropriate length.

TM 2.1

INSIDE MICROMETER

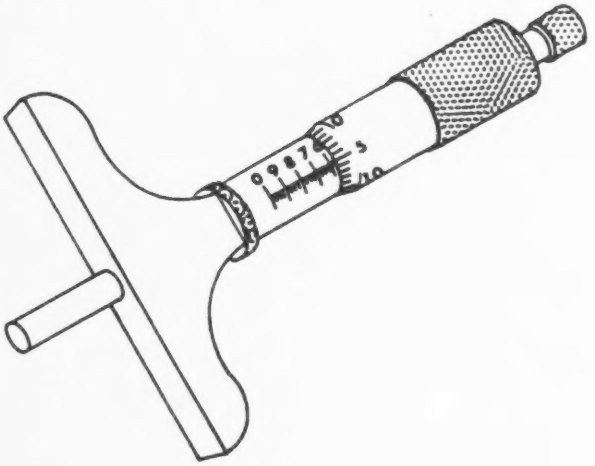


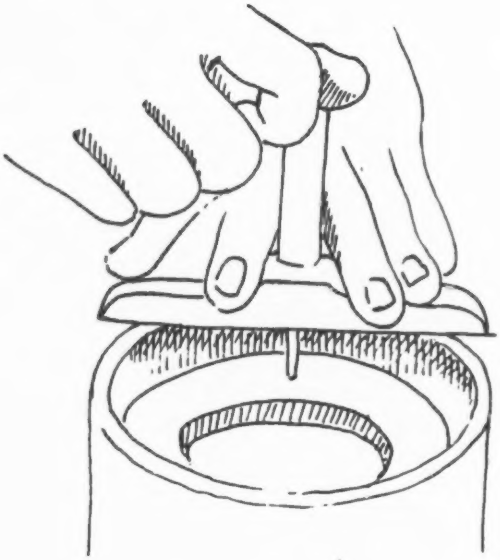
Inside micrometer



Measuring with inside micrometer

DEPTH MICROMETER





JS 2.1

MEASURE WORKPIECE WITH INSIDE MICROMETER

Equipment:

Inside micrometer set
Various pipes with inside diameters ranging from 1" to 3"

Procedure:	Evaluation 3	 2	 1	 N
1. Put the pipe sections in order, by sight, according to the inside diameters. Set the inside micrometer to measure from 1" to 2".	—	—	—	—
2. Measure the smaller pipe sections with a 1-2" inside micrometer. Record the measurements.	—	—	—	—
3. When the 1-2" set-up will no longer accommodate workpiece diameters, install the 2-3" extension and measure the rest of the pipe sections.	—	—	—	—
4. Check measurements with the instructor.	—	—	—	—
Average of above evaluations*	—	—	—	—

*This average (one-third) with that of JS 1.1 (two-thirds) completes the student's evaluation for competency C11: Measure workpiece with micrometers.

JS 2.2

MEASURE WORKPIECE WITH DEPTH GAGES

Equipment:

Depth micrometer set
Various rectangular workpieces
Surface plate
Pocket rule

NOTE: This exercise simulates depth measurements by measuring down the side of workpieces to the top of a surface plate.

Procedure:	Evaluation 3	2	1	N
1. Obtain the equipment and place a workpiece on the surface plate. Estimate the height of the workpiece. Select and install an appropriate spindle according to the estimate.	—	—	—	—
2. Place the depth micrometer base across the workpiece with the spindle extending down the side of the work. Hold the base down securely with the thumb and forefinger. Turn the thimble until the spindle face contacts the surface plate.	—	—	—	—
3. Read the height of the workpiece on the barrel and record the measurement.	—	—	—	—
4. Repeat the measurements with additional workpieces. Check measurements with the instructor.				
Average of above evaluations*	—	—	—	—

*This average is the student's final evaluation for competency C10: Measure workpiece with depth gages.

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT V: MEASURING WITH MICROMETERS

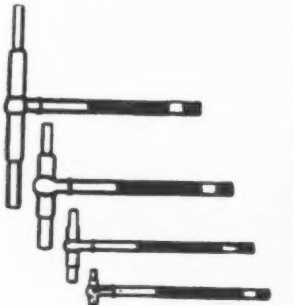
LESSON 3: INDIRECT MICROMETER MEASUREMENTS

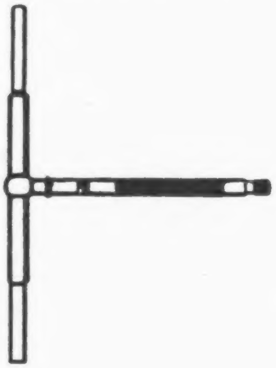
I. Telescoping-hole gages (used with outside micrometer calipers)

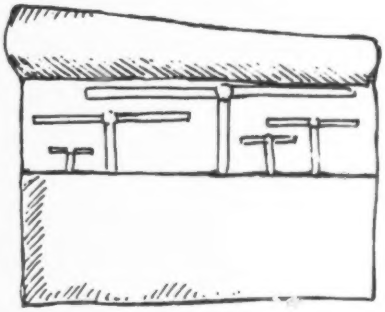
   A. Collapse the gage and set it in the hole so that ends are snug.

   B. Pull the gage into the hole until ends are pulled through the hole being measured. Lock the gage. Remove it from the hole.

   C. Measure the distance across the ends of the gage with an outside micrometer.





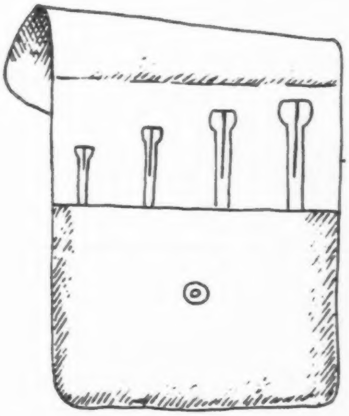


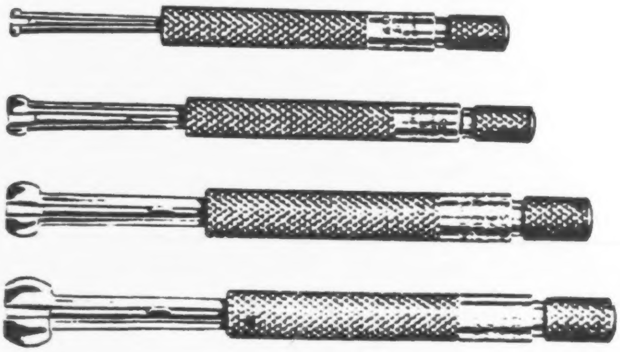
II. Small-hole gages (used with outside micrometer calipers)

   A. Collapse the gage and insert it into the hole to be measured.

   B. Expand the gage until it touches both sides of the hole.

   C. Tilt the gage and remove it. Measure across the gage with an outside micrometer.





MEASURE WORKPIECE WITH TELESCOPE AND HOLE GAGES

Equipment:

Various workpieces with drilled holes of diameters ranging from 0.125" to 2.000" (3.2-50 mm)
Set of small-hole gages
Set of telescoping-hole gages
0-1" (0-25 mm) outside micrometer
1-2" (25-50 mm) outside micrometer

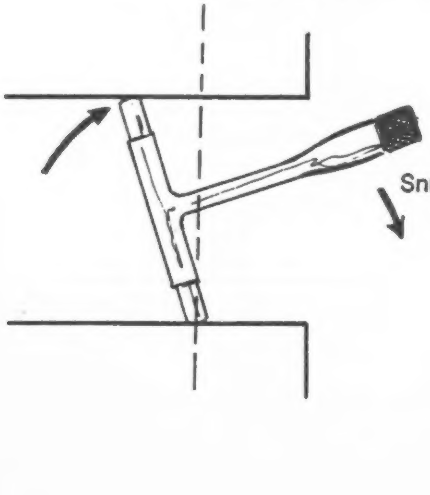
Procedure: Evaluation 3 2 1 N

NOTE: Select holes with diameters of 0.500" (13 mm) or less when using small-hole gages.

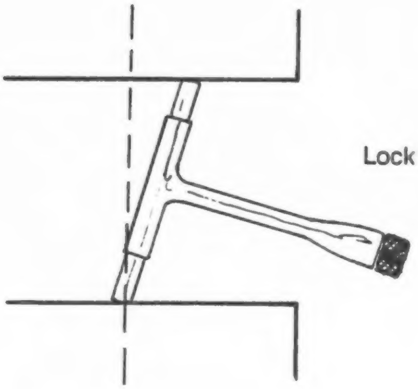
1. Try various small-hole gages in the hole to be measured until the gage of the correct range is identified. ___ ___ ___ ___
2. Collapse the gage and insert it into the hole. Expand the gage until it touches both sides of the hole. ___ ___ ___ ___
3. Tilt the gage and remove it. Measure across the gage with an outside micrometer. ___ ___ ___ ___
4. Check the measurements with the instructor. ___ ___ ___ ___

   NOTE: Select holes with 0.500" (13 mm) or greater diameters when using telescoping-hole gages.

5. Determine the appropriate telescoping-hole gage for the hole to be measured. ___ ___ ___ ___
6. Collapse the gage and set it in the hole so that ends are snug. Pull the gage into the hole until ends are pulled through the hole being measured. Lock the gage. Remove it from the hole. ___ ___ ___ ___



Snug the lock and pull one side down until past perpendicular.



Lock and pull out gage.

7. Measure the distance across the ends of the gage with an outside micrometer. — — — —

8. Check measurements with the instructor. — — — —

9. Return tools and materials. — — — —

Average of above evaluations* — — — —

*This average is the student's final evaluation for competency C13: Measure workpiece with telescope and hole gages.

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT V: MEASURING WITH MICROMETERS

LESSON 4: USING THREAD MEASURING WIRE

I. Techniques for measuring threads or pitch diameter

  A. Plug and ring gages

  B. Thread micrometer

  C. Roll thread snap gage

  D. Three-wire method

II. Three-wire method

  A. Uses three thread-measuring wires

  B. Accepted as the most accurate and recommended by the National Bureau of Standards

  C. Based on the "best wire size" for pitch and diameter

    1. The best wire size is based on the wire touching and being tangent to the sides of the thread at the pitch diameter.

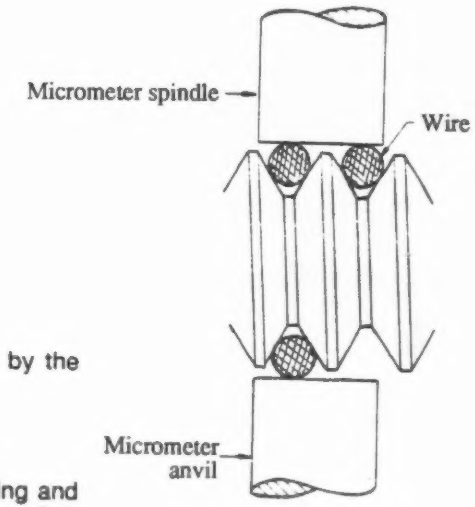
    2. Wires must not contact the crest.

  D. The wire size is determined by calculation or from a chart.

  E. Wires are placed in the thread grooves and the measurement is taken across wires with an outside micrometer caliper.

  F. Thread measuring wires come in sets to accommodate various thread pitches. The wires should be round and straight to within 0.00002" and accurate to within 0.00003".

  G. The formula for calculating the pitch diameter from measurements made over wires for a standard 60° form thread is as follows.



$$E = M + \frac{806603}{N} - 3G$$

E = pitch diameter
N = number of threads per inch
G = diameter of wires
M = measurement over wires

JS 4.1

MEASURE WORKPIECE WITH THREAD WIRES AND MICROMETERS

Equipment:

0-1" outside micrometer
Set of thread measuring wires with a "best wire size" chart
Various threaded parts of 1" diameter or less
Pocket scale
Thread pitch gage

Procedure:	Evaluation 3	 2	 1	 N
1. Select a threaded part to be gauged and use either a pocket scale or thread pitch gage to determine the pitch of the thread.				
2. Read the chart and select the "best" wire diameter for measurement.				
3. Place the wires across the threads, two on one side and one on the other.				
4. Place the micrometer across the wires and take the measurement; record it.				
5. Calculate the pitch diameter with the formula below. $E = M + \frac{806603}{N} - 3G$ E = pitch diameter N = number of threads per inch G = diameter of wires M = measurement over wires				
6. Clean up area and return tools and materials.				
Average of above evaluations*				

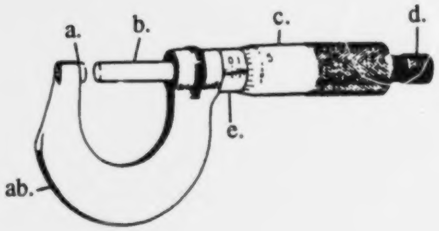
*This average is the student's final evaluation for competency C20: Measure workpiece with thread wires and micrometers.

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT V: MEASURING WITH MICROMETERS

UNIT TEST

Identify the parts of the outside micrometer.



____ 1. Anvil

____ 2. Sleeve

____ 3. Frame

____ 4. Thimble

____ 5. Spindle

Select the option which best answers the question or completes the statement.

____ 6. A plain inch micrometer will measure to within __________ .

a. 0.1"
b. 0.01"
c. 0.001"
d. 0.0001"
e. None of the above

____ 7. A plain metric micrometer will measure to within __________ .

a. 0.5 mm
b. 0.05 mm
c. 0.01 mm
d. 0.1 mm
e. None of the above

____ 8. How many threads per millimeter does a metric micrometer have?

a. 1
b. 2
c. 25
d. 50
e. None of the above

____ 9. How many threads per inch on its screw does an inch micrometer have?

a. 10
b. 25
c. 40
d. 80
e. None of the above

____ 10. A metric vernier caliper can read to within ____________ .

- a. 0.1 mm
- b. 0.01 mm
- c. 0.001 mm
- d. 0.0001 mm
- e. None of the above

____ 11. An inch vernier micrometer can read to within ____________ .

- a. 0.1"
- b. 0.01"
- c. 0.001"
- d. 0.0001"
- e. None of the above

____ 12. Which is true when using inside and depth micrometers?

- a. "Feel" is an important requirement for accurate use.
- b. The proper extension rod must be selected.
- c. Measurements are similar to those made with a micrometer caliper.
- d. Calibration is performed as when using micrometer calipers.
- e. All of the above

____ 13. Which tools would not be used for gauging external screw threads?

- a. Inside micrometer
- b. Thread measuring wire
- c. Outside micrometer caliper
- d. Ring gage
- e. None of the above

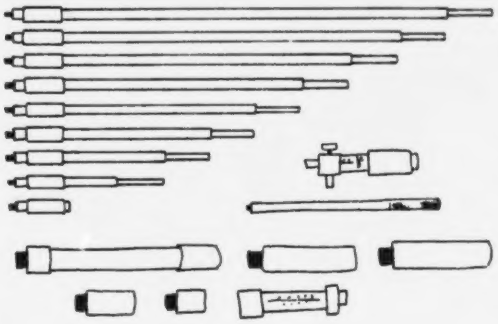
____ 14. What is the "best wire size" for the three-wire thread measuring method is based upon?

- a. Thread diameter
- b. Inside diameter
- c. Root diameter
- d. Pitch or number of threads per inch
- e. None of the above

Identify the illustrated tools.

____ 15.	a.	Depth micrometer	d.	Telescoping-hole gage
____ 16.	b.	Inside micrometer	e.	Small-hole gage
____ 17.	c.	Outside micrometer	ab.	Thread measuring wire
___ 18.				

15.



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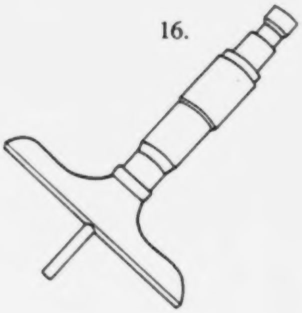

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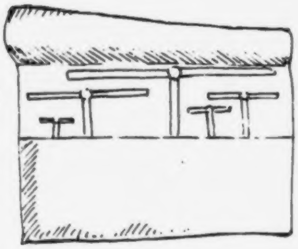

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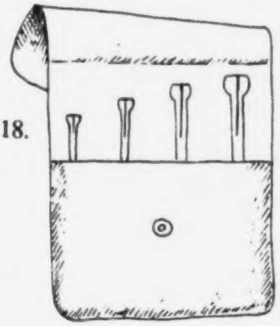


ANSWERS TO UNIT TEST

1.	a	(C11)
2.	e	(C11)
3.	ab	(C11)
4.	c	(C11)
5.	b	(C11)
6.	c	(C11)
7.	c	(C11)
8.	b	(C11)
9.	c	(C11)
10.	c	(C11)
11.	d	(C11)
12.	e	(C10, C11)
13.	a	(C11, C20)
14.	d	(C20)
15.	b	(C11)
16.	a	(C10)
17.	d	(C13)
18.	e	(C13)

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT VI: MEASUREMENT AND LAYOUT ON A SURFACE PLATE

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to perform a variety of techniques for precision measurement and layout on a surface plate using height gages, surface gages, gage blocks, dial indicators and sine bars.

SPECIFIC OBJECTIVES

After completion of the lessons in this unit, the student should be able to:

1.1 Describe gage blocks and their grades.

1.2 Use and care for gage blocks. (competency C18, JS 1.1 and JS 2.2)

2.1 Match measurement terms and definitions.

2.2 Describe surface plates.

2.3 Identify tools used with surface plates.

2.4 Lay out workpiece on a surface plate. (competencies C15 and C16, JS 2.1)

2.5 Measure and inspect workpiece on surface plate. (competencies C17 and C19, JS 2.2)

2.6 Check work with sine bar. (competency C21, JS 2.3)

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT VI: MEASUREMENT AND LAYOUT ON A SURFACE PLATE

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plans

- 1. Lesson 1: GAGE BLOCKS
    - a. Information outline
    - b. Transparency masters

        TM 1.1: Wringing gage blocks
        TM 1.2: Wringing gage blocks (cont.)

    - c. Assignment sheet

        AS 1.1: Assembling gage blocks

    - d. Answers to assignment sheet
    - e. Job sheet

        JS 1.1: Use and care for gage blocks

- 2. Lesson 2: MEASUREMENT AND INSPECTION ON A SURFACE PLATE
    - a. Information outline
    - b. Job sheets

        JS 2.1: Lay out workpiece on a surface plate
        JS 2.2: Measure and inspect workpiece on a surface plate
        JS 2.3: Check work with sine bar

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. Precision Measurement in the Metalworking Industry. Vocational Education Program for National Defense Industries. Endicott, NY: State Education Department, The University of the State of New York, March 1941.

2. Olivo, C. Thomas. Advanced Machine Tool Technology. North Scituate, MA: Breton Publishers, 1982.

3. Repp, Victor E., and Willard J. McCarthy. Machine Tool Technology. 5th ed. Bloomington, IL: McKnight Publishing Co., 1984.

4. Repp, Victor E., Willard J. McCarthy and Oswald A. Ludwig. Metalwork Technology and Practice. Bloomington, IL: McKnight Publishing Co., 1982.

NOTES TO THE INSTRUCTOR

A. Suggested supplemental materials

   1. Layout of a Semi-Precision Workpiece (MS-84-301) (video). Sedalia, MO: State Fair Community College, 1984. (Available for purchase from SFCC; available for loan from Missouri Vocational Resource Center, phone 800/392-7217 or 314/882-9610)

   2. Precision Tools, Gages and Saws (Catalog No. 28). 1st ed. Athol, MA: The L. S. Starrett Company, 1986.

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT VI: MEASUREMENT AND LAYOUT ON A SURFACE PLATE

LESSON 1: GAGE BLOCKS

I. Description of gage blocks (also known as Johansson or "Jo" blocks)

   A. Gage block--piece of alloy steel with a square or rectangular cross-section and a measuring surface on each end. Gage blocks are the primary measurement standard in most industries and are used to calibrate all measuring tools and gages and set up machinery.

   B. Gage block set--standard set of 81 blocks consisting of the dimensions listed below.

      1. One ten-thousandths series--9 blocks (.1001-.1009)
      2. One thousandth series--49 blocks (.101-.149)
      3. Fifty thousandths series--19 blocks (.050-.950)
      4. Inch series--4 blocks (1-4")

   C. Grades of gage blocks

      1. AA--accurate to ± two millionths; laboratory standard gage block
      2. A--accurate to ± four millionths; general industry standard gage block
      3. B--accurate to ± eight millionths

II. Care and use of gage blocks

   A. Care tips

      1. New blocks are shipped with a protective coating which must be removed with kerosene or another light solvent before the blocks can be used.
      2. Be careful when gauging a part made of hard materials since it may be as hard as the gage block and can scratch the measuring surfaces of the block.
      3. Do not touch the gauging surface any more than necessary.
      4. Blocks should be wiped clean and coated lightly with a non-corrosive lubricant.

   B. Wringing is the process of joining gage blocks together. The measuring surfaces are so smooth and flat that the blocks will "stick" together when wrung. **(TM 1.1, 1.2)**

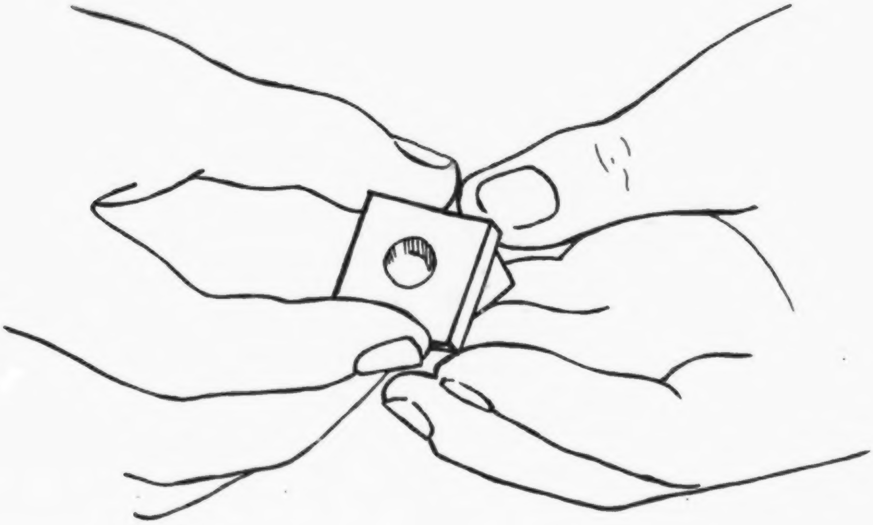
      1. Two blocks to be wrung are brought together with corners oriented to prevent them from scratching measuring surfaces.
      2. The blocks can then be aligned. If clean, they will adhere to one another.
      3. Blocks that are wrung are easily separated by twisting and pulling them apart.

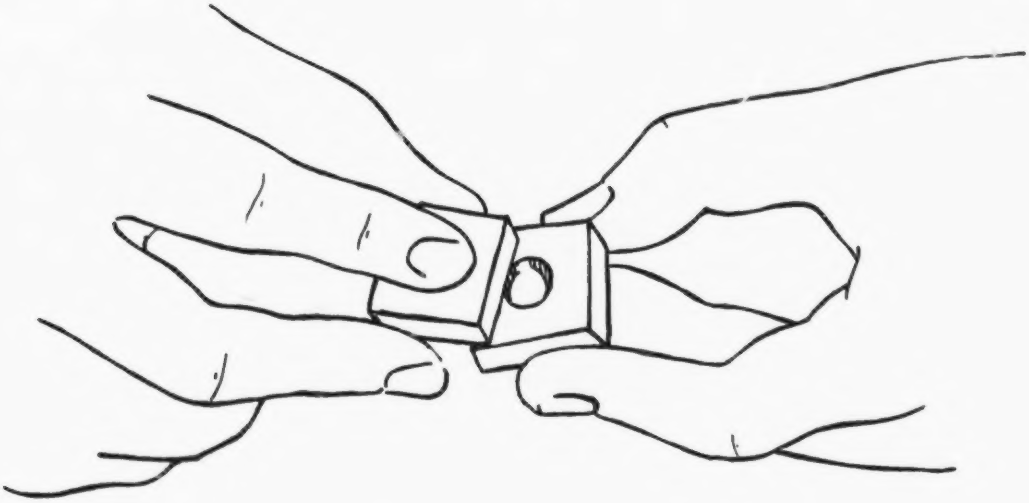
C. Example of measurement: 1.4373 inch

1. Write the figure on paper.
2. Select a block with a 3 in the fourth decimal place (block 0.1003).
3. Subtract this amount from the original figure.
4. Eliminate the last two figures other than zero by selecting the 0.1370 block. Subtract from the remaining figure.
5. Eliminate the last figure to the right, other than zero, by selecting the 0.200 block.
6. Eliminate the 1.000 by selecting the 1.000 block.
7. Remember to always reduce from right to left.
8. Multiple combinations can produce any given reading.

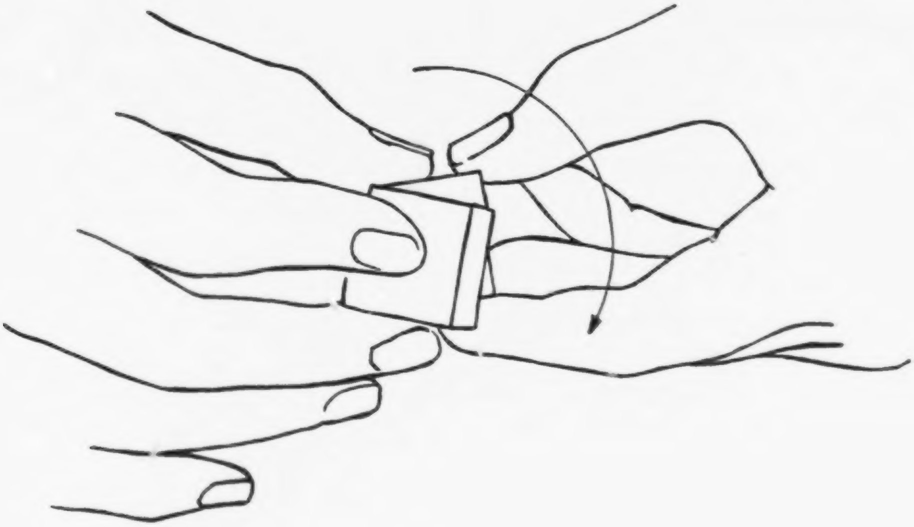
TM 1.1

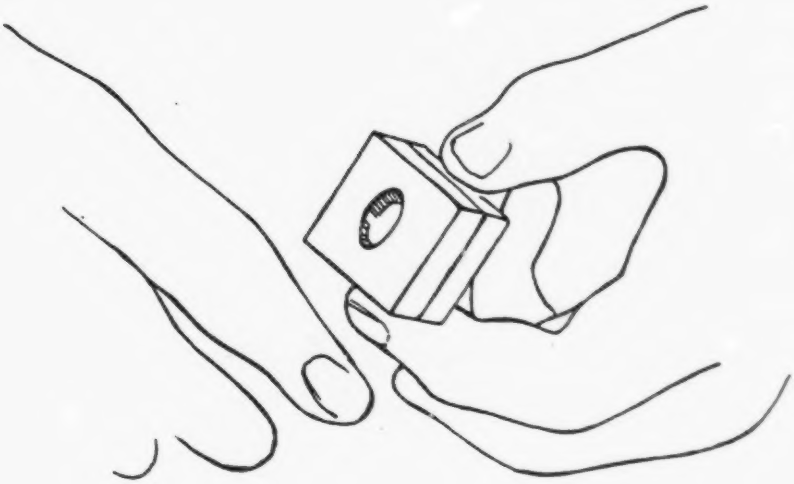
WRINGING GAGE BLOCKS





WRINGING GAGE BLOCKS (CONT.)





ASSEMBLING GAGE BLOCKS

For this assignment sheet, assume the use of a standard 81-gage block set containing the following:

Ten-thousandths series--nine blocks (.1001, .1002, .1003, .1004, .1005, .1006, .1007, .1008, .1009)

Thousandths series--49 blocks (.101, .102, .103, .104, .105, .106, .107, .108, .109, .110, .111, .112, .113, .114, .115, .116, .117, .118, .119, .120, .121, .122, .123, .124, .125, .126, .127, .128, .129, .130, .131, .132, .133, .134, .135, .136, .137, .138, .139, .140, .141, .142, .143, .144, .145, .146, .147, .148, .149)

Fifty thousandths series--19 blocks (.050, .100, .150, .200, .250, .300, .350, .400, .450, .500, .550, .600, .650, .700, .750, .800, .850, .900, .950)

Inch series--four blocks (1.000, 2.000, 3.000, 4.000)

Suggest a combination of blocks for each measurement using a standard 81-gage block set. Show your work, and use the minimum number of blocks.

1. 1.2345

2. 2.3400

3. 7.4569

4. 5.0093

ANSWERS TO AS 1.1

1. .1005 + 1.34 + 1.000
2. .200 + .140 + 2.000
3. .1009 + .106 + .250 + 4.000 + 3.000
4. .1003 + .109 + .800 + 4.000

JS 1.1

USE AND CARE FOR GAGE BLOCKS

Equipment:

Gage block cleaner
Lint-free shop cloth
Standard 81-gage block set
0-1" micrometer
1-2" micrometer

Procedure: Evaluation 3 2 1 N

1. Obtain equipment and assemble the gage blocks needed for a reading of 0.0751". __ __ __ __

2. Clean the faces of each block by spraying with the gage block cleaner and wiping with the cloth. __ __ __ __

3. Wring the blocks together. __ __ __ __

   NOTE: Be careful to prevent gage block corners from damaging the measuring surfaces.

4. Check the measurement with a micrometer. __ __ __ __

5. Assemble the gage blocks for each of the following dimensions and repeat steps 2-4. __ __ __ __

   a. 0.09876
   b. 1.256
   c. 1.4578

   NOTE: Clean the faces of the micrometer before measuring. Do not exert excessive pressure. Do not slide the faces of the micrometer anvil and spindle across the measuring surface of the gage block.

6. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials. __ __ __ __

Average of above evaluations* __ __ __ __

*This average is the student's partial evaluation for competency C18: Measure workpiece with gage blocks.

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT VI: MEASUREMENT AND LAYOUT ON A SURFACE PLATE

LESSON 2: MEASUREMENT AND INSPECTION ON A SURFACE PLATE

I. Terms and definitions

   A. Angularity--surface at a specified angle from a reference plane

   B. Circularity--roundness of a particular part feature such as a hole

   C. Cylindricity--condition of a curved surface in which all points on the surface are equidistant from a central axis

   D. Datum--reliable reference surface from which part features can be gauged

   E. Flatness--degree to which a part feature is flat. All elements are within one plane.

   F. Geometric tolerance--tolerance applied to non-dimensional aspects of part feature control (parallelism, perpendicularity, etc.)

   G. Parallelism--surface with points equidistant from a reference plane

   H. Perpendicularity--surface or feature at right angles to a reference plane

   I. Straightness--degree to which a part is straight or without bend or wind

   J. Total indicator run-out (TIR)--total reading on an indicator when moved around or across a surface; also known as full indicator movement (FIM)

II. Description of surface plates

   A. A surface plate provides a primary reference datum for all precision measurement and inspection activities.

   B. The face of the surface plate is extremely flat and straight.

   C. Materials

      1. Cast iron

      2. Semi-steel

      3. Polished granite

III. Tools and instruments used with surface plates

   A. Measuring instruments

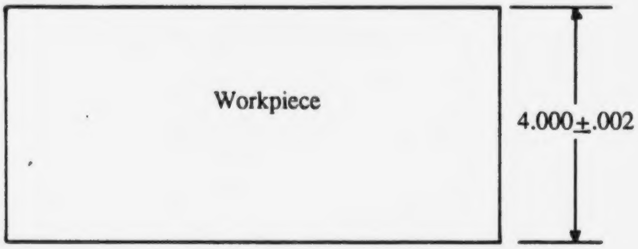
      1. Height gages

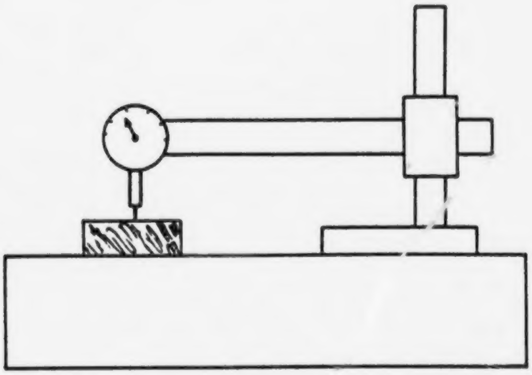
         a. The types are vernier and digital.

         b. Accessories include the scriber and indicator holder.

        2. Surface gages to hold and move the scriber
        3. Gage blocks
        4. Dial-type test indicators and accessories to inspect surfaces and set-up
        5. Precision square to check 90° angles
    B. Set-up tools
        1. Sine bars and plates are used in conjunction with gage blocks to lay out angles.
        2. Angle blocks are high-precision 90° blocks.
        3. Parallels are precision-ground blocks used to elevate the workpiece or as a reference surface.
        4. Matching pairs of V-blocks are used to hold round work accurately.
        5. Toolmaker's clamps provide precise alignment of the jaws for a variety of work-holding applications.

IV. Inspection and measurement examples
    A. Inspect a workpiece for parallelism.
        1. The illustrated workpiece must have surfaces that are parallel to within 0.002". The illustrated set-up is one way to inspect this part.





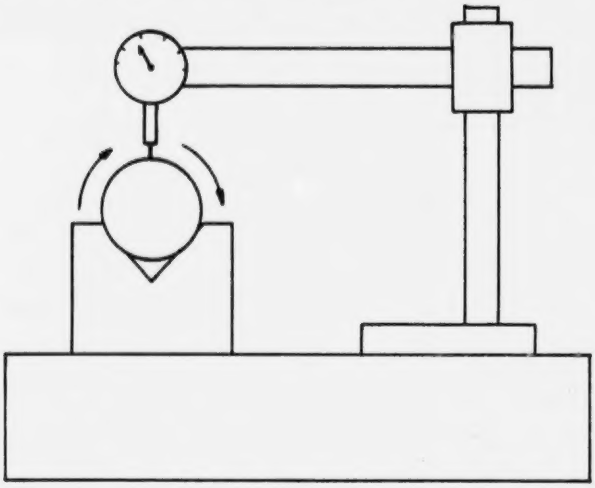
2. The surface gage is moved across the surface plate and the indicator movement is noted.

3. If the total movement is less than 0.002", the part can be accepted.

B. Inspect a part for circularity (roundness).

1. The illustrated workpiece is set up to be inspected for circularity.

2. Rotate workpiece slowly and note indicator movement.

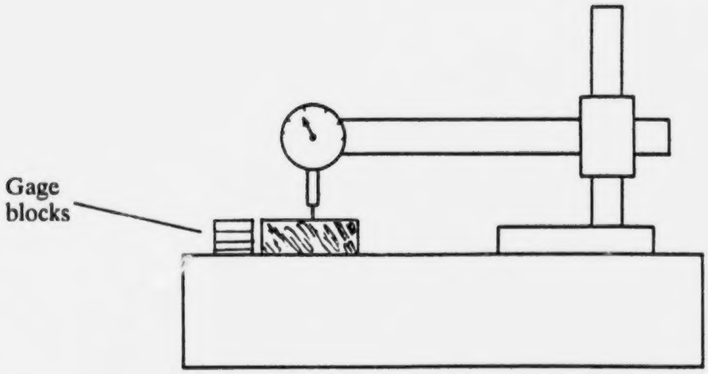


C. Measure the height of a workpiece with a height gage and gage blocks.

1. The workpiece to be gauged should be 3.025" in height.

2. Gage blocks are combined to obtain this reading.

3. A vernier height gage equipped with a dial indicator is used.

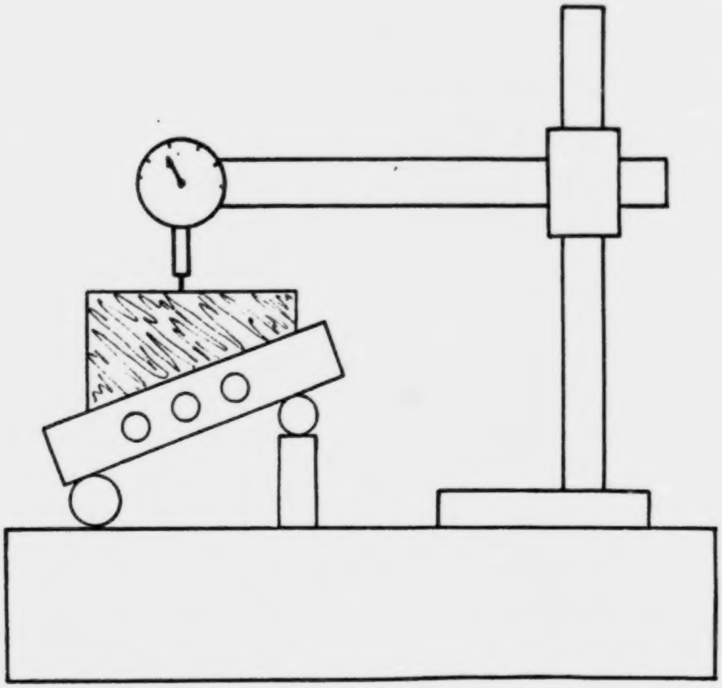


  - a. The dial indicator is brought into contact with gage blocks using the height gage adjustment.
  - b. Set the indicator dial to zero while still in contact.
  - c. Note the height gage reading.
  - d. Raise the indicator from the gage blocks and lower onto the workpiece.
  - e. The indicator is made to read zero and the height gage reading will indicate any difference between the height of the part and the gage blocks.

D. Inspect angularity with a sine bar and a test indicator.

1. The illustrated workpiece is to be gauged for an angularity of 25° with a FIM not exceeding 0.001".
2. Place the angular surface so that it is parallel to the surface plate (reference plane).
   - a. Set the sine bar at 25°.
   - b. Calculate the required height of the gage blocks (length of the opposite side). The centers of the two rods on the base of the sine bar are known to be exactly 5" apart and the sine of 25° is 0.42262.

     SIN angle = opp. ÷ hyp. or 0.42262 = x ÷ 5 = 2.1131"

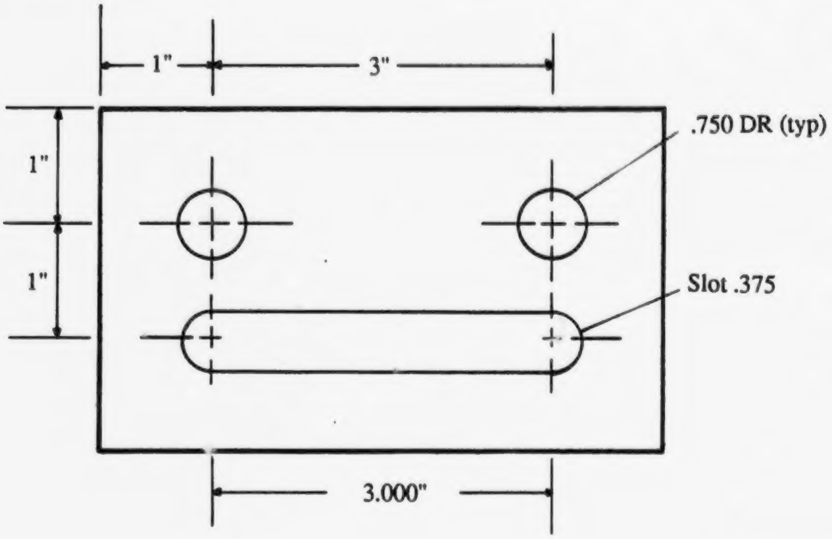


JS 2.1

LAY OUT WORKPIECE ON A SURFACE PLATE

Equipment:

Surface plate
Height gage
Angle block
Layout blue
Workpiece, 1x2x3" (see drawing)



Procedure:	Evaluation 3	 2	 1	 N
1. Assemble the equipment. Coat one face of the workpiece with layout blue.	___	___	___	___
2. Lay out part features (hole centers and slot) according to the drawing.	___	___	___	___
3. Place scriber attachment in height gage. Turn the workpiece on its side and back with the angle block so that it does not fall over.	___	___	___	___
4. Set the height gage to read the distance from the side of the workpiece to the hole center. Scribe this line by sliding the height gage along the workpiece with the scriber engaged.	___	___	___	___
5. Set the height gage to read the distance from the side of the workpiece to the near side of the slot. Scribe this line.	___	___	___	___
6. Set the height gage to read the distance from the side of the workpiece to the far side of the slot. Scribe this line.	___	___	___	___
7. Set the height gage to read the distance from the side of the workpiece to the second set of hole centers. Scribe this line by sliding the height gage along the workpiece with the scriber engaged.	___	___	___	___

8. Scribe the intersection of the hole centers. Turn the workpiece on end and set the height gage for the distance from the end to the nearest hole intersection. Scribe a short line to indicate the intersection of these dimensions. ___ ___ ___ ___

9. Set the height gage for the distance from the end to the farthest hole intersection. Scribe a short line to indicate the intersection of the dimensions. ___ ___ ___ ___

10. Check the part against the drawing. ___ ___ ___ ___

11. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials. ___ ___ ___ ___

Average of above evaluations* ___ ___ ___ ___

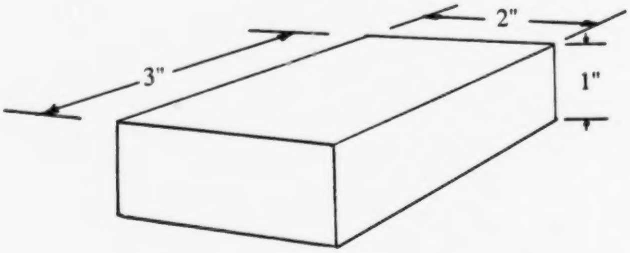
*This average is the student's final evaluation for competencies C15 and C16.

JS 2.2

MEASURE AND INSPECT WORKPIECE ON A SURFACE PLATE

Equipment:

Dial indicator
Surface gage
Surface plate
Workpiece, 1x2x3" (see drawing)
Gage block set



Procedure:	Evaluation 3	 2	 1	 N
1. Assemble equipment.	___	___	___	___
2. Gauge the dimensions of the workpiece in the order of 1, 2, 3. Turn the workpiece face down as shown below. Place a 1" gage block from the set so that one measuring surface is against the surface plate.	___	___	___	___
3. Mount the indicator on the surface gage. Sweep the top surface of the gage block with the indicator. Zero the indicator dial by twisting the dial until the indicator needle reads zero while in contact with the top of the gage block.	___	___	___	___
4. Without adjusting the indicator or the surface gage, slide the surface gage so that the indicator reads on the face of the workpiece. Read the indicator. (The difference between the zero setting obtained on the gage block and the workpiece indicator reading is the amount that the part feature dimension varies from the specified dimension of the part.)	___	___	___	___
5. Repeat steps 2-4 for the remaining faces using 2" and 3" gage block assemblies.	___	___	___	___
6. As directed by instructor, prepare for next job sheet or clean up area and return tools and materials.	___	___	___	___
Average of above evaluations*	___	___	___	___

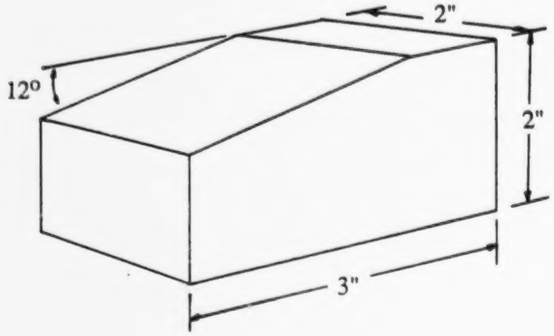
*This average is the student's final evaluation for competencies C17, C18 and C19.

JS 2.3

CHECK WORK WITH SINE BAR

Equipment:

Surface plate
Surface gage with scriber
Gage block set
5" sine bar
Workpiece (see drawing)



Procedure:	Evaluation 3	 2	 1	 N
1. Assemble equipment. The surface to be inspected requires that a 12° angle be measured and that there be no more than 0.005 full indicator movement along this surface.	—	—	—	—
2. Assemble the needed gage blocks. Calculate the required height of the gage blocks (length of the opposite side) with the following formula. Sine 12° = opp. ÷ hyp. NOTE: Obtain the value of sine for the angle from a table of trigonometric functions.	—	—	—	—
3. Set up the sine bar and workpiece. Mount indicator on the surface gage. Bring indicator into contact at one end of the angular surface of the workpiece. Set indicator to zero.	—	—	—	—
4. Slide the indicator over the full length of the angular surface of the workpiece. Note the difference between the reading from one end to the other. This reading (FIM) should be compared with the 0.005 angular geometric tolerance. (If the reading is greater than 0.005 FIM, the part would be rejected.)	—	—	—	—
5. Clean up area and return tools and materials.	—	—	—	—
Average of above evaluations*	—	—	—	—

*This average is the student's final evaluation for competency C21: Check and/or lay out workpiece with sine bar.

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT VI: MEASUREMENT AND LAYOUT ON A SURFACE PLATE

UNIT TEST

Select the option which best answers the question or completes the statement.

____ 1. Which is a precision device most commonly used to calibrate other measuring tools in the machine shop?

a. Micrometer
b. Gage block
c. Inside micrometer
d. Surface plate
e. None of the above

____ 2. Which of the following is not a common material for surface plates?

a. Cast iron
b. Granite
c. Semi-steel
d. Marble
e. None of the above

____ 3. How many gage blocks does a standard set contain?

a. 10
b. 71
c. 75
d. 81
e. 100

____ 4. Which of the following is a precision device used to lay out and inspect angles?

a. Dial indicator
b. Sine bar
c. Gage block
d. Cast surface block
e. None of the above

____ 5. What is another name for gage blocks?

a. Svenson gages
b. Johannson (Jo) blocks
c. Olson parallels
d. Olaf's plates
e. None of the above

____ 6. How are the most accurate gage blocks designated?

a. ZZ
b. AA
c. A
d. A-
e. None of the above

____ 7. Which process involves sticking gage blocks together to form a specified measurement?

a. Waxing
b. Gluing
c. Waning
d. Wringing
e. None of the above

Match the terms with definitions.

____ 8. Surface is at a specified angle from a reference plane

____ 9. Surface or feature is at right angles to a reference plane

____ 10. Degree to which all elements or part features are within one plane

____ 11. Reliable reference surface from which part features can be gauged

____ 12. Surface has all points equidistant from a reference plane

____ 13. Degree to which a part is without bend or wind

____ 14. Roundness of a particular part feature such as a hole

____ 15. Applied to non-dimensional aspects of part feature control including parallelism, perpendicularity, etc.

____ 16. Condition of a curved surface in which all points on the surface are equidistant from a central axis

a. Angularity
b. Circularity
c. Cylindricity
d. Datum
e. Flatness
ab. Geometric tolerance
ac. Parallelism
ad. Perpendicularity
ae. Straightness

ANSWERS TO UNIT TEST

1.	b	(C18)
2.	d	(C16)
3.	d	(C18)
4.	b	(C21)
5.	b	(C18)
6.	b	(C18)
7.	d	(C18)
8.	a	
9.	ad	
10.	e	
11.	d	
12.	ac	
13.	ae	
14.	b	
15.	ab	
16.	c	

MODULE: MEASUREMENT AND BLUEPRINT READING
UNIT VII: GO, NO-GO INSPECTION METHODS

UNIT OBJECTIVE

In this unit the student will learn to use various measurement inspection tools which can be used to quickly gauge part dimensions in a production setting. Among these devices are snap gages, and plug and ring gages.

SPECIFIC OBJECTIVES

Upon completion of this unit, the student should be able to:

1.1 Review terms related to production tolerancing.

1.2 Identify gages for production measurement.

1.3 Describe types and applications of permanent gages.

1.4 Describe the care of plug and ring gages.

1.5 Set and use snap gages. (competency C14, JS 1.1)

1.6 Check work with plug and ring gages. (competency C14, JS 1.2)

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT VII: GO, NO-GO INSPECTION METHODS

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plan

  1. Lesson 1: PRINCIPLE AND TECHNIQUES FOR PRODUCTION

    a. Information outline

    b. Transparency master

      TM 1.1: Parts of a snap gage

    c. Handout

      HO 1.1: Types of gages

    c. Job sheets

      JS 1.1: Set and use snap gages
      JS 1.2: Check work with plug and ring gages

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. Precision Measurement in the Metalworking Industry. Vocational Education Program for National Defense Industries. Endicott, NY: State Education Department, The University of the State of New York, March 1941.

2. Olivo, C. Thomas. Advanced Machine Tool Technology. North Scituate, MA: Breton Publishers, 1982.

3. Repp, Victor E., and Willard J. McCarthy. Machine Tool Technology. 5th ed. Bloomington, IL: McKnight Publishing Co., 1984.

4. Repp, Victor E., Willard J. McCarthy and Oswald A. Ludwig. Metalwork Technology and Practice. Bloomington, IL: McKnight Publishing Co., 1982.

NOTES TO THE INSTRUCTOR

A. Suggested approach to teaching this unit

1. Job sheet 1.2 is built around two common items in the shop with relatively tight tolerances. For ring gauging, use commercial .500" drill rod. For plug gauging, use drilled and reamed holes (.500") in a workpiece.

B. Suggested supplemental material

1. Precision Tools, Gages and Saws (Catalog No. 28). 1st ed. Athol, MA: The L. S. Starrett Company, 1986.

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT VII: GO, NO-GO INSPECTION METHODS

LESSON 1: PRINCIPLES AND TECHNIQUES FOR PRODUCTION

I. Production tolerancing

  A. Review of terms

    1. Allowance--intentional difference in the dimensions of two mating parts so that a desired fit is obtained; also clearance

    2. Basic size--specified dimension to which tolerance is applied

    3. Nominal size--specified, blueprint size without tolerance allowances

    4. Fit--relative degree of looseness or tightness between two mating parts

    5. Gage--device for determining whether or not a one or more dimensions of a manufactured part are within specified limits

    6. Go, no-go gage--gage which incorporates and tests upper and lower limits of part dimension

    7. Tolerance--allowable variation in a part feature dimension from the specified dimension

  B. Fits

    1. Running or sliding fits permit clearance between the mating parts so that they will move past one another.

    2. Interference fits have zero or negative clearance between the mating parts. (Also called press fit)

II. Gages for production measurement

  A. Types of gages (HO 1.1)

    1. Typical go/no-go gages are permanently included in the construction of an instrument and may or may not be adjustable.

       Examples: snap, ring and plug gages

    2. Gages such as the dial gage and dual indicator indicate variation from a master part; they must be set to zero.

    3. Gages such as micrometers indicate dimensions on a scale.

  B. Classes of go/no-go gages

    1. Class XX--refers to master gage used for set-up; precision lapped to laboratory standards

    2. Class X--working inspection gage; precision lapped

    3. Class Y--working inspection gages with good lapped surfaces but higher tolerances

4. Class Z--working gage used when tolerances are wide or commercial specifications apply; not fully ground and polished

III. Permanent gages

A. Types of permanent gages (TM 1.1)

1. Plug gages--used to check dimensions of straight or tapered holes; go/no-go type

2. Ring gages--used to check dimensions of straight or tapered shafts. These require two gages--one for the upper limit and one for the lower limit.

3. Snap gage--production gage with two pairs of anvils machined (solid snap gage) or set (adjustable snap gage) to provide upper and lower limit inspection of part dimensions; generally has infrequent application in the machine shop

B. Application

1. Plug gage

a. The go section is longer than the no-go section; insert go portion first.

b. If go section will enter hole without resistance, the lower limit has been achieved. If go section will not enter hole, the part should be rejected.

c. If no-go section will not enter hole, the part is within tolerance. If no-go section enters hole, the upper limit of tolerance has been exceeded; reject the part.

d. The go plug gage regulates the minimum dimension of a hole being gaged.

2. Ring gage

a. Ring gages generally requires two gages--one for the upper limit and one for the lower limit.

b. Check upper limit first; if shaft will enter gage, the part is within the upper limit; if it will not enter gage, the part is rejected.

c. Check lower limit; if shaft will not enter gage, the part is within lower limit tolerance. If it will enter, the part must be rejected.

d. A go ring gage controls the upper maximum dimension of the part being gauged.

3. Adjustable snap gage

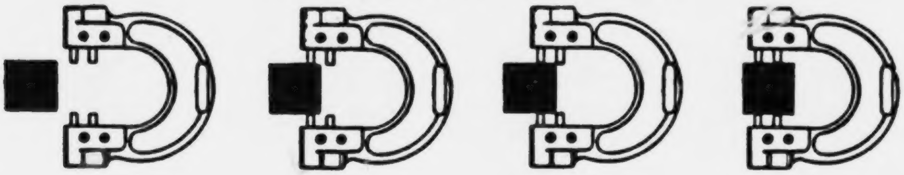
a. Anvils are set using gage blocks.

b. Set outer anvils to upper limit (go); set inner anvils to lower limit (no-go).

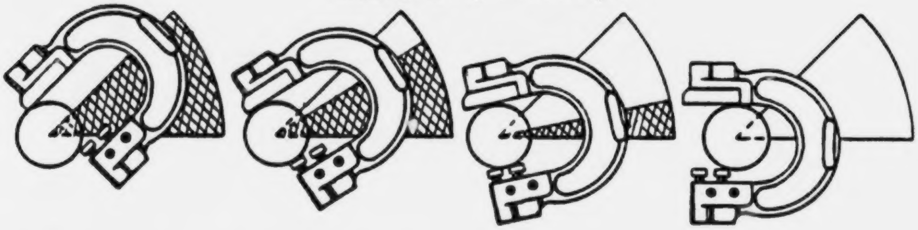
c. If part will pass through first pair of anvils, continue checking; if not, reject the part.

d. If the part will not pass through the inner set of anvils, the part is good; if the part will pass through, it is rejected.

Snap gaging an object with parallel surfaces



Snap gaging a cylindrical object



IV. Care of plug and ring gages

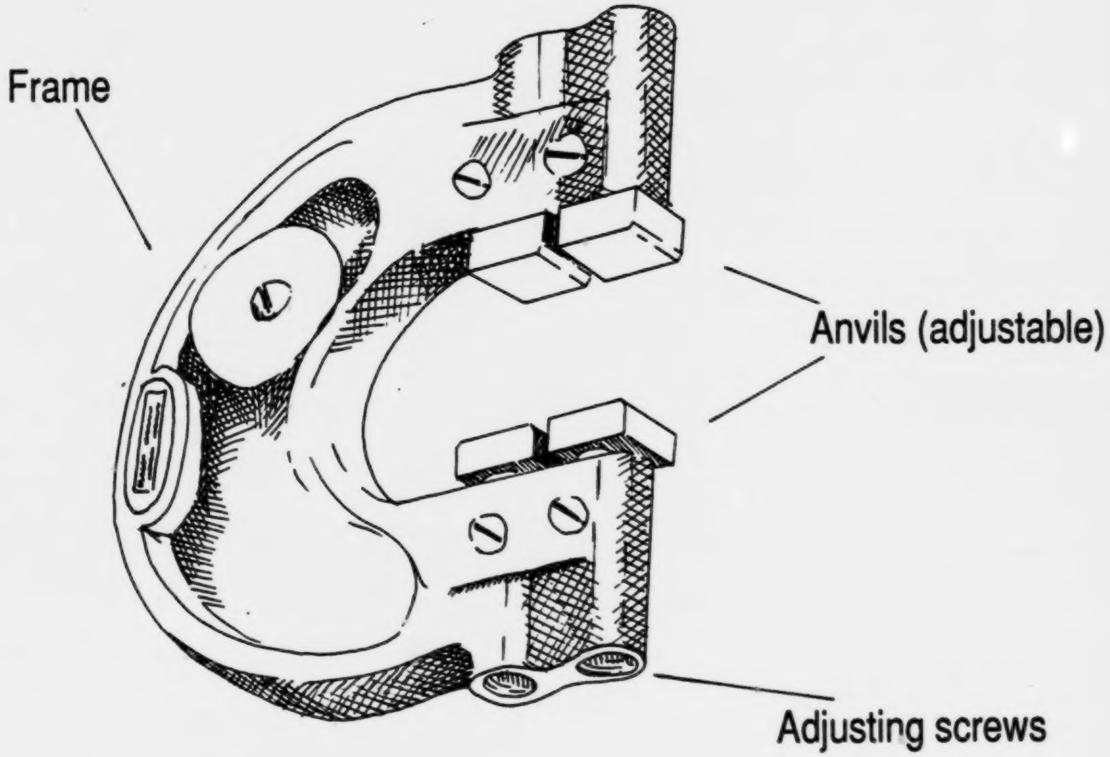
A. Take care when gauging some materials as they can damage the gage. This is especially true of cast iron and cast aluminum.

B. Hold the gage in your hand when using it. Never clamp in a vise as this will distort the gage.

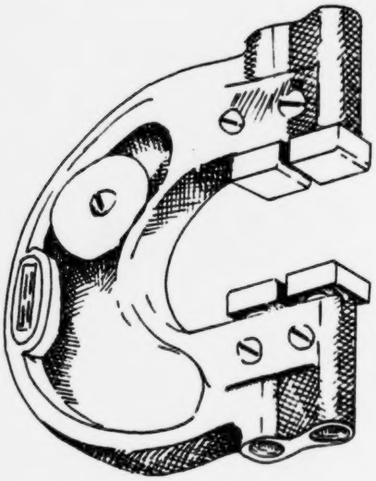
C. Generally, more care must be taken with plug gages than with ring gages as the gauging surfaces on a ring gage are internal and protected. Always handle gages with care.

TM 1.1

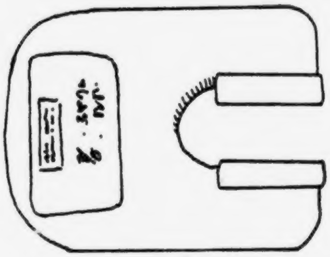
PARTS OF A SNAP GAGE



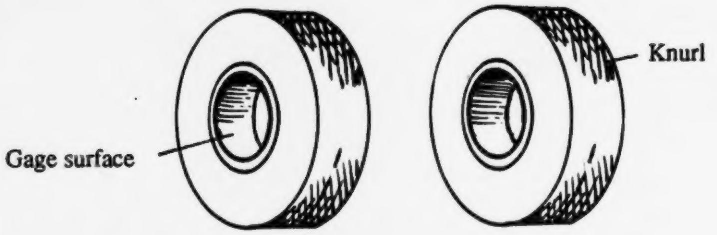
TYPES OF GAGES



Adjustable snap gage

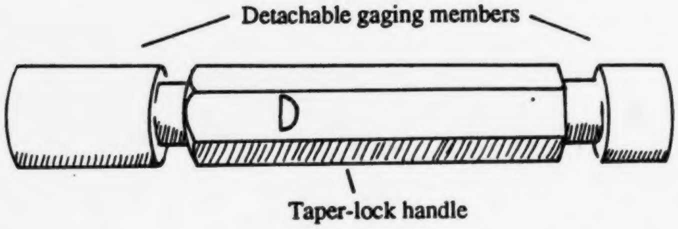


Solid snap gage



Ring gages

Plug gage



JS 1.1

SET AND USE SNAP GAGES

Equipment:

Adjustable-limit snap gage 0-1"
Screwdriver or hex wrench, as needed
Set of gage blocks

	Evaluation			
Procedure:	3	2	1	N
1. Obtain gage blocks, snap gage and other necessary tools. Using various gage block combinations, set the snap gage to the following tolerances.	—	—	—	—

a. .500 ± .002

b. .375 ± .005

c. .125 ± .0002

NOTE: Remember that the high end of the tolerance should be set on the outer anvils (go) and low end set on the inner anvils (no-go).

2. Ask the instructor to inspect each setting. Return tools and materials.

*This average is the student's partial evaluation for competency C14: Check work with gages, i.e. plug and ring gages.

JS 1.2

CHECK WORK WITH PLUG AND RING GAGES

Equipment:

Short length of .500" drill rod
Workpiece with .500" reamed hole
Three ring gages (.5005, .5000, .4995)
Three plug gages (.5005, .5000, .4995)

Procedure:	Evaluation 3	 2	 1	 N
1. Using plug gages, gauge the reamed holes in the workpiece.	___	___	___	___
2. From the results of your gauging, determine which gage could be considered go and which would be no-go.	___	___	___	___
3. Using ring gages, gauge the drill rod sample.	___	___	___	___
4. From the results of your gauging, determine which gage could be considered go and which would be no-go.	___	___	___	___
5. Return tools and materials.	___	___	___	___
Average of above evaluations*	___	___	___	___

*This average completes the student's evaluation for competency C14: Check work with gages, i.e. plug and ring gages.

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT VII: GO, NO-GO INSPECTION METHODS

UNIT TEST

Select the option which best answers the question or completes the statement.

____ 1. Which term indicates the specified dimension to which a tolerance is applied?

a. Allowance
b. Basic size
c. Fit
d. Interference
e. Nominal

____ 2. Which term indicates the relative degree of looseness or tightness between mating parts?

a. Fit
b. Basic size
c. Running
d. Interference
e. Nominal

____ 3. Which of the following gages can be set to zero and used for gauging from a master part?

a. Ring gage
b. Dial indicator
c. Plug gage
d. Micrometer
e. None of the above

____ 4. Which term indicates zero or negative clearance between two mating parts?

a. Ring gage
b. Interference
c. Running
d. Clearance
e. None of the above

____ 5. Which of the following gage classes has the tightest tolerance?

a. Z
b. Y
c. X
d. XX
e. None of the above

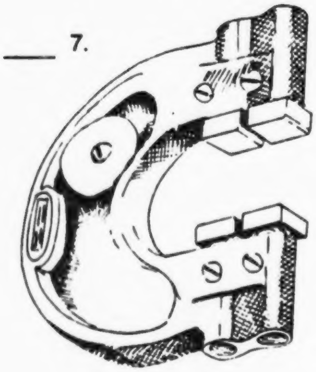
____ 6. Which term refers to the allowable variation in a part feature from a specified dimension?

a. Fit
b. Basic size
c. Go, no-go
d. Tolerance
e. Nominal size

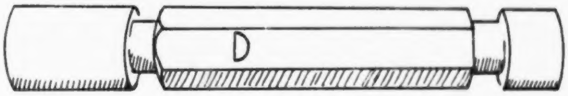
Match the names of the gages with the illustrations shown below.

a. Gage block
b. Plug gage
c. Ring gage
d. Snap gage
e. Spline gage

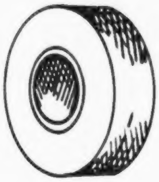
____ 7.



____ 8.



____ 9.



Select the option which best answers the question or completes the statement.

____ 10. Which of the following tools can be used to set snap gage anvils?

a. Micrometer
b. Dial indicator
c. Ring gage
d. Gage blocks
e. None of the above

____ 11. Why are plug gages more susceptible to damage than ring gages?

a. They are not as hard.
b. They are made to closer tolerances.
c. Plug gages have gauging surface exposed.
d. Gages cannot be clamped in a vise.
e. None of the above

____ 12. Which is a gage classification with relatively loose tolerances used to gage for commercial standards?

a. XX
b. X
c. Y
d. Z
e. None of the above

____ 13. When setting a snap gage, the lower limit is set on which anvil?

a. Fixed or solid
b. Outer
c. Inner
d. Frame
e. None of the above

ANSWERS TO UNIT TEST

1. b
2. a
3. b (C14)
4. b
5. d (C14)
6. d (C14)
7. d (C14)
8. b (C14)
9. c (C14)
10. d (C14)
11. c (C14)
12. d (C14)
13. c (C14)

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT VIII: COMMON DRAFTING SYMBOLS

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to interpret the meaning of common drafting symbols. This knowledge will be evidenced by achieving the specified score on assignment sheets and the unit test.

SPECIFIC OBJECTIVES

After completion of the lessons in this unit, the student should be able to:

1.1 Describe the purpose of ANSI and ISO standards for drafting symbols.

1.2 Match terms and definitions.

1.3 Illustrate common drafting symbols.

1.4 Identify form and proportion guidelines for drafting symbols.

2.1 Match terms and definitions.

2.2 Identify symbols for various types of holes (drilled, reamed, bored, counterbored, countersunk).

2.3 Identify the types and methods of screw thread representation.

2.4 Select surface texture symbols and the processes associated with them. (competency D1)

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT VIII: COMMON DRAFTING SYMBOLS

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plans

1. Lesson 1: IDENTIFICATION

   a. Information outline

   b. Assignment sheets

      AS 1.1: Terms and definitions
      AS 1.2: Drafting symbols

2. Lesson 2: APPLICATIONS

   a. Information outline

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. Dimensioning and Tolerancing (ANSI Y14.5M). New York: The American Society of Mechanical Engineers, 1982.

2. Geotsch, David L., and John A. Nelson. Technical Drawing and Design. Albany, NY: Delmar Publishers, Inc., 1986.

3. Nickolaisen, Robert. Machine Drafting and Design. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1986.

4. Taylor, David L. Machine Trades Blueprint Reading. Albany, NY: Delmar Publishers, Inc., 1985.

B. Technical manuals

1. Abridged Standards for Engineering Specification 890350, Part I. Armonk, NY: International Business Machines, Inc., 1985.

2. Modern Drafting Practices and Standards Manual. Schenectady, NY: General Electric Company, 1978.

NOTES TO THE INSTRUCTOR

A. Suggested supplemental materials

1. Publications

   a. Dimensioning and Tolerancing (ANSI Y14.5M). New York: The American Society of Mechanical Engineers, 1982.

   b. Geotsch, David L., and John A. Nelson. Technical Drawing and Design. Albany, NY: Delmar Publishers, Inc., 1986.

   c. Nickolaisen, Robert. Machine Drafting and Design. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1986.

   d. Taylor, David L. Machine Trades Blueprint Reading. Albany, NY: Delmar Publishers, Inc., 1985.

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT VIII: COMMON DRAFTING SYMBOLS

LESSON 1: IDENTIFICATION

I. Use for universal drafting language

- A. Blueprints using commonly accepted symbols are the language through which the machinist, designer and others communicate accurately.
- B. Certain drafting techniques are recognized as standard. This standardization makes it possible for those who interpret drawings to produce identical parts--even if they work in different countries.
- C. ISO (International Standards Organization) and ANSI (American National Standards Institute, Inc.)
  1. Work was begun to establish engineering standards in the 1950s by several English-speaking countries (U.S., Great Britain, Canada, Australia).
  2. Worldwide meetings have continued through the years to improve these standards. U.S. participation (ANSI) has contributed greatly.
  3. Several ANSI techniques have been introduced to--and accepted by--the ISO. ISO standards have also been adopted by ANSI.

  NOTE: See ANSI standard Y14.5M (Dimensioning and Tolerancing), published by the American Society of Mechanical Engineers, for more detailed information.

II. Terms and definitions

		ANSI Y14.5M symbol	ISO symbol
A.	Arc length--symbol is used to denote that a linear dimension is a curved measurement	$\overset{\frown}{105}$	NONE
B.	Blueprint reading--process of interpreting a print to form a mental picture of how the completed object will look		
C.	Coaxiality--showing a common axis or axes	◎	◎
D.	Concentricity--showing a common center	◎	◎
E.	Conical taper--cone-shaped piece specified by one of the following methods: (1) a basic taper and a basic diameter, (2) a size tolerance combined with a profile of a surface tolerance applied to the taper or (3) a toleranced diameter at both ends of a taper and a toleranced length	⌲	⌲
F.	Datum--theoretically exact point, axis or plane; origin from which the location or geometric characteristics of a part's features begin		

G.	Dimension origin--used to indicate that a toleranced dimension between two features begins from one of these features	⌽→	**NONE**
H.	Feature control frame--geometric tolerance for an individual feature specified by a feature control frame divided into compartments containing the geometric characteristic symbol and tolerance factor	⌖│Ø0.5Ⓜ│A│B│C	⌖│Ø0.5Ⓜ│A│B│C
I.	Material condition (maximum or least)--size, type and state of material being used to produce part	Ⓜ	Ⓜ
J.	Number of times/places--denotes number of times or places a process is to be completed	**8X**	**8X**
K.	Radius, spherical radius, spherical diameter--symbols (in radius or diameter) which precede the value of a dimension or tolerance	R SR SØ	R NONE NONE
L.	Runout tolerance--composite tolerance used to control the functional relationship of one or more features of a part to a datum axis		
M.	Sectional view--cut-away representation which shows internal shape and construction of a part		
N.	Slope--used for specifying taper and incline for conical and flat tapers; symbol is always shown with the vertical leg to the left.	⌳	⌳
O.	Square--indicates that a single dimension applies to a cubed shape	□	□
P.	Taper--ratio of the difference in diameters of two sections of a cone compared to the distance between these sections		
Q.	Tolerance--total amount by which a dimension may vary		
R.	Views--grouping of lines according to surfaces of the object being viewed; lines indicate shape, details and size of an object		

III. Additional ANSI symbols

		ANSI Y14.5M symbol	ISO symbol
A.	Straightness	—	—
B.	Flatness	⏥	⏥
C.	Circularity	○	○
D.	Cylindricity	⌭	⌭
E.	Profile of a line	⌒	⌒
F.	Profile of a surface	⌓	⌓
G.	All around--profile	←⊖	**NONE**
H.	Angularity	∠	∠
I.	Perpendicularity	⊥	⊥

J.	Parallelism	//	//
K.	Position	⌖	⌖
L.	Symmetry	NONE	⌯
M.	Circular runout	*↗	↗
N.	Total runout	*⌰	⌰
O.	At maximum material condition	Ⓜ	Ⓜ
P.	At least material condition	Ⓛ	NONE
Q.	Regardless of feature size	Ⓢ	NONE
R.	Projected tolerance zone	Ⓟ	Ⓟ
S.	Diameter	Ø	Ø
T.	Basic dimension	$\boxed{50}$	$\boxed{50}$
U.	Reference dimension	(50)	(50)
V.	Datum feature	$\boxed{\text{-A-}}$	*▲ OR *▲$\boxed{A}$
W.	Datum target	Ø6/A1	Ø6/A1
X.	Target point	×	×
Y.	Counterbore/spotface	⌴	NONE
Z.	Countersink	⌵	NONE
AA.	Depth/deep	↧	NONE
AB.	Dimension not-to-scale	$\underline{15}$	$\underline{15}$

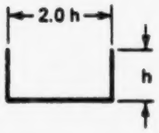
NOTE: An asterisk (*) indicates that the symbol may be filled in.

IV. Form and proportion of dimensioning symbols

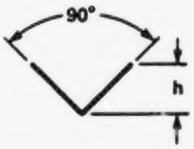
A. To accurately specify geometric tolerances, a preferred form and proportion of symbols has been adopted.

B. Symbols illustrated below from Dimensioning and Tolerancing (Y14.5M) are grouped according to like elements in construction. The letter "h" designates letter height.

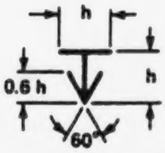
NOTE: See ANSI Y14.2M for more line weight and letter height guidelines.



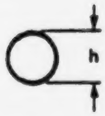
COUNTERBORE
OR SPOTFACE



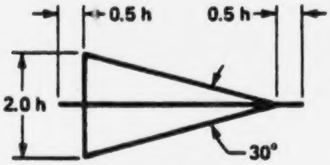
COUNTERSINK



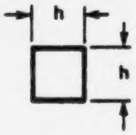
DEPTH
(OR DEEP)



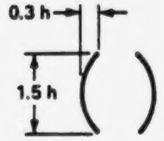
DIMENSION ORIGIN



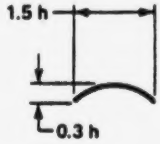
CONICAL TAPER



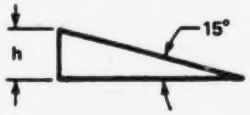
SQUARE (SHAPE)



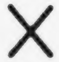
REFERENCE



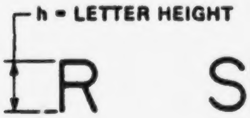
ARC LENGTH



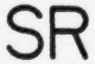
SLOPE



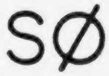
PLACES, TIMES OR BY



RADIUS



SPHERICAL RADIUS



SPHERICAL DIAMETER

TERMS AND DEFINITIONS

Match the following terms and definitions.

____ 1. Composite tolerance used to control the functional relationship of one or more features of a part to a datum axis

____ 2. Cone-shaped piece specified by one of three methods

____ 3. Cut-away representation which shows internal shape and construction of a part

____ 4. Geometric tolerance for an individual feature specified by a control area divided into compartments

____ 5. Grouping of lines according to surfaces of the object being viewed; lines indicate shape, details and size of an object

____ 6. Indicates that a toleranced dimension between two features begins from one of these features

____ 7. Process of interpreting a print to form a mental picture of how the completed object will look

____ 8. Ratio of the difference in diameters of two sections of a cone compared to the distance between these sections

____ 9. Showing a common center

____ 10. Showing a common axis or axes

____ 11. Theoretically exact point, axis or plane; origin from which the location or geometric characteristics of a part's features begin

____ 12. Total amount by which a dimension may vary

____ 13. Used for specifying taper and incline for conical and flat tapers; symbol is always shown with the vertical leg to the left.

a. Blueprint reading

b. Coaxiality

c. Concentricity

d. Conical taper

e. Datum

ab. Dimension origin

ac. Feature control frame

ad. Runout tolerance

ae. Sectional view

bc. Slope

bd. Taper

be. Tolerance

cd. Views

Select the option which answers the question or completes the statement.

____ 14. What is the significance of blueprints to machine shop?

a. To facilitate ease of operation among equipment
b. To duplicate a part accurately
c. To allow control of a shop's output
d. All of the above

AS 1.2

DRAFTING SYMBOLS

Illustrate the following drafting symbols according to ANSI Y14.5M standards.

____ 1. Coaxiality

____ 2. Conical taper

____ 3. Dimension origin

____ 4. Radius

____ 5. Slope

____ 6. Square

____ 7. Flatness

____ 8. Cylindricity

____ 9. Profile of a surface

____ 10. All around--profile

____ 11. Perpendicularity

____ 12. Parallelism

____ 13. Position

____ 14. Symmetry

____ 15. Circular runout

____ 16. Total runout

____ 17. At maximum material condition

____ 18. At least material condition

____ 19. Regardless of feature size

____ 20. Projected tolerance zone

____ 21. Diameter

____ 22. Reference dimension

____ 23. Datum feature

____ 24. Datum target

____ 25. Counterbore/spotface

____ 26. Countersink

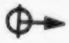
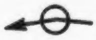
____ 27. Depth/deep

____ 28. Dimension not-to-scale

ANSWERS TO AS 1.1

1. ad
2. d
3. ae
4. ac
5. cd
6. ab
7. a
8. bd
9. c
10. b
11. e
12. be
13. bc
14. b

ANSWERS TO AS 1.2

1. ◎
2. ⌲
3. 
4. R
5. ⌳
6. □
7. ⏥
8. ⌭
9. ⌓
10. 
11. ⊥
12. //
13. ⌖
14. NONE
15. ↗
16. ⌰
17. Ⓜ
18. Ⓛ
19. Ⓢ
20. Ⓟ
21. Ø
22. (50)
23. $\boxed{\text{-A-}}$
24.

25. ⌴
26. ⌵
27. ↧
28. $\underline{15}$

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT VIII: COMMON DRAFTING SYMBOLS

LESSON 2: APPLICATIONS

NOTE: As the part or mechanism becomes more and more complex, the designer, drafter, engineer and machinist must use precise methods to describe the object adequately.

I. Terms and definitions

   A. Counterboring--making a hole by machining to a larger diameter to allow for a recessed bolt or pin

   B. Countersinking--process of removing metal around a hole's edge to provide a seat for conical-shaped screw heads and rivets; to provide a seat for work held between centers in a lathe, mill or similar machine

II. Symbols for types of holes

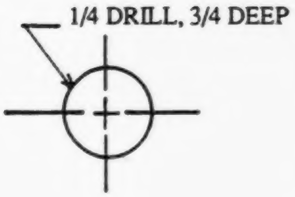
   A. Drilled, reamed, bored

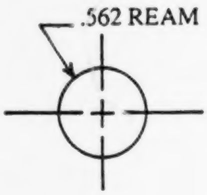
      1. Drilled holes passing through a workpiece are drawn in a profile with a note indicating the drill number, letter or decimal inch and fraction size, followed by the process notation "DRILL". This indicates to the machinist that a standard drill is used with a normal tolerance.

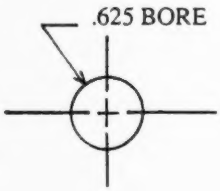
      2. A decimal value is commonly placed in parenthesis following the drill size number or letter.

      3. When noting in metric, the diameter is shown without the drill process note.

      4. Reamed or bored holes are commonly dimensioned by indicating the hole size and the process notation "REAM" or "BORE".



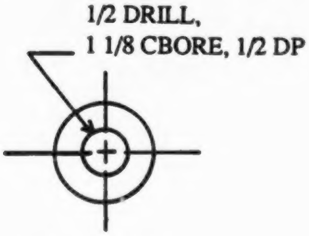




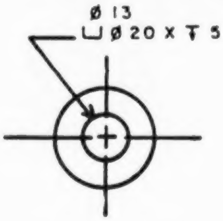
   B. Counterbored

      1. Counterbored holes provide a flat surface for the bolt or pin to seat against.

2. Hole depth is equal to the height of the fastener head or nut. Common fasteners using counterboring are socket-head cap screws and fillister-head screws.



Fractional inch



ANSI standard

C. Countersunk

1. Countersinking is sometimes used to remove burrs and chamfer holes.

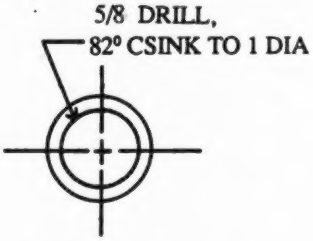
2. Countersunk holes are dimensioned by giving the following information.

   a. Diameter of the hole

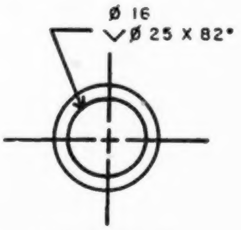
   b. Angle at which the hole is to be countersunk

   c. Diameter at the hole's large end

   d. Number of holes to be countersunk



Fractional inch



ANSI standard

III. Screw thread representation

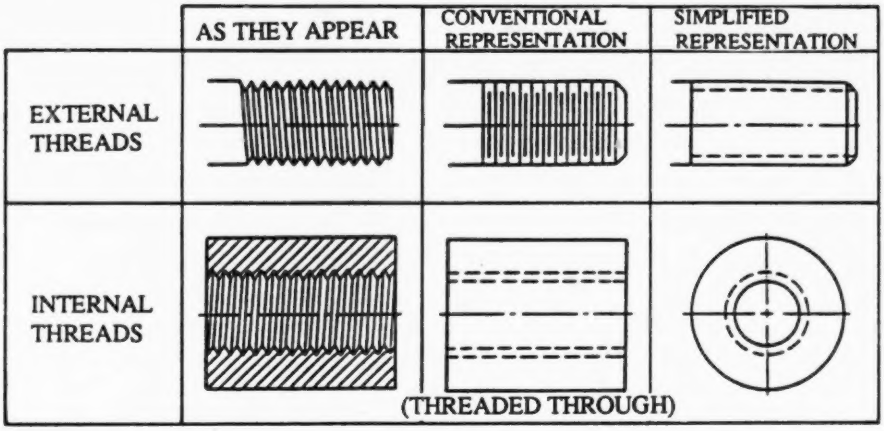
A. Two types--external threads produced on a part's outside and internal threads cut on the inside

B. Methods of representation

1. As they appear to the eye

2. By conventional representation

3. By simplified representation



C. Each illustration is accompanied by a series of dimensions, letters and numbers which--when combined--give full specifications for cutting and measuring the threads

IV. Surface texture

A. The symbol used to indicate details of surface texture resembles a check mark.

1. Usually, only surface roughness height is indicated by placing a number above the small part of the check mark.

2. Other characteristics of surface texture can be specified, as well.

3. The point of the symbol is placed on the surface line, on an extension line or is directed to the surface by a leader.

B. In the chart below are some recommended roughness height values (in micro-inches), a description of the surface and surface production processes.

Roughness height rating	Surface description	Process
1000 ✓	Very rough	Saw and torch cutting, forging or sand casting
500 ✓	Rough machining	Heavy cuts and coarse feeds in turning, milling and boring
250 ✓	Coarse	Very coarse surface grind; rapid feeds in turning, planing, milling, boring and filing
125 ✓	Medium	Machining operations with sharp tools, high speeds, fine feeds and light cuts
63 ✓	Good machine finish	Sharp tools, high speeds, extra fine feeds and cuts
32 ✓	High-grade machine finish	Extremely fine feeds and cuts on lathe, mill and shapers required. Easily produced by center-less, cylindrical and surface grinding

16 ✓	High-quality machine finish	Very smooth reaming or fine cylindrical or surface grinding
8 ✓	Very fine machine finish	Fine honing and lapping of surface
2-4 ✓	Extremely smooth machine finish	Extra fine honing and lapping of surface

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT VIII: COMMON DRAFTING SYMBOLS

UNIT TEST

Match the following terms to definitions.

____ 1. Process of machining a hole to a larger diameter to allow for a recessed bolt or pin

____ 2. Cone-shaped piece specified by one of three methods

____ 3. Cut-away representation which shows internal shape and construction of a part

____ 4. Geometric tolerance for an individual feature specified by a control area divided into compartments

____ 5. Grouping of lines according to surfaces of the object being viewed; lines indicate shape, details and size of an object

____ 6. Process of removing metal around a hole's edge to provide a seat for conical-shaped screw heads and rivets

____ 7. Process of interpreting a print to form a mental picture of how the completed object will look

____ 8. Ratio of the difference in diameters of two sections of a cone compared to the distance between these sections

____ 9. Showing a common center

____ 10. Showing a common axis or axes

____ 11. Theoretically exact point, axis or plane; origin from which the location or geometric characteristics of a part's features begin

____ 12. Total amount by which a dimension may vary

____ 13. Used for specifying taper and incline for conical and flat tapers; symbol is always shown with the vertical leg to the left.

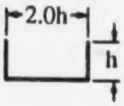
a. Blueprint reading
b. Coaxiality
c. Concentricity
d. Conical taper
e. Counterboring
ab. Countersinking
ac. Datum
ad. Dimension origin
ae. Feature control frame
bc. Runout tolerance
bd. Sectional view
be. Slope
cd. Taper
ce. Tolerance
de. Views

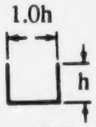
Select the option which answers the question or completes the statement.

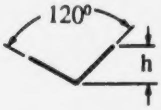
____ 14. Which of the following symbols is drawn differently for ISO standards (as compared to ANSI Y14.5M)?

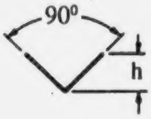
a. Datum feature
b. Datum target
c. Parallelism
d. Perpendicularity
e. Target point

____ 15. According to ANSI standards, which of the following illustrations is proper for showing countersinking?

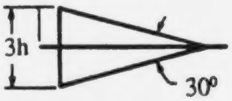
a.


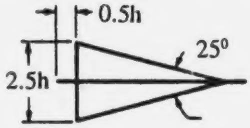
c.


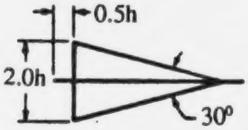
b.


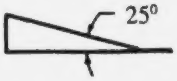
d.


____ 16. When showing a conical taper by ANSI standards, which of the following is most accurate?

a.


c.


b.


d.


____ 17. The symbol for slope should have a ______-degree angle on one side and be ________ tall.

a. 10°, 1 h
b. 15°, 1 h
c. 15°, 1.5 h
d. 20°, 1.5 h
e. 20°, 1.7h

____ 18. How tall should the letters be when showing radius, spherical radius or spherical diameter?

a. .5 h
b. .75 h
c. 1 h
d. 1.5 h
e. 1.7 h

____ 19. When symbolizing hole dimensions, a ___________ is commonly placed in parentheses following the drill size number or letter; _____________ notations are shown without the drill process note.

a. Metric number, decimal
b. Decimal value, counterboring
c. Metric value, countersinking
d. Decimal value, metric
e. Decimal value, decimal

____ 20. Which piece of information is unnecessary for dimensioning countersunk holes?

a. Diameter of the hole
b. Angle at which hole is to be countersunk
c. Radius at hole's large end
d. Number of holes
e. All of the above

____ 21. Screw threading is represented by what kind of illustration?

a. Only internal
b. Internal or external
c. Only external
d. Both internal or external
e. Two-way

____ 22. Methods of showing screw threading include which representation?

a. As they appear
b. Conventional
c. Simplified
d. All of the above
e. None of the above

____ 23. The point of the surface texture symbol is __________ .

a. Placed on the surface line
b. Placed on an extension line
c. Directed to the surface by a leader
d. Any of the above
e. None of the above

____ 24. A coarse surface texture is indicated as ____________ ; __________ feeds are required in turning, planing, milling, boring and filing.

a. 500√ ; coarse, slow
b. 250√ ; rapid
c. 125√ ; high speeds and fine
d. 63√ ; high speeds and extra-fine
e. 31√ ; slow

Short answer

25. Why are commonly accepted drafting symbols used in the U.S.?

ANSWERS TO UNIT TEST (D1)

1. ad
2. d
3. ae
4. ac
5. cd
6. ab
7. a
8. bd
9. c
10. b
11. e
12. be
13. bc
14. a
15. d
16. b
17. b
18. c
19. d
20. c
21. b
22. d
23. d
24. b

25. So that the machinist, designer and others have a universal language, regardless of location

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT IX: BLUEPRINT INTERPRETATION

UNIT OBJECTIVE

Upon completion of this unit, the student will be able to interpret blueprints and make sketches from finished workpieces. This knowledge will be evidenced by achieving the specified score on the job sheet and unit test.

SPECIFIC OBJECTIVES

After completion of the lessons in this unit, the student should be able to:

1.1 Differentiate between object and hidden lines.

1.2 Describe the purpose of section lines.

1.3 Differentiate between uses of center and extension lines.

1.4 Describe the location of dimension lines and leaders on a print.

1.5 Identify cutting plane lines.

1.6 Identify appropriate break lines for given workpieces.

1.7 Describe uses of phantom lines. (competency D2)

2.1 Describe and locate proper views (top, front, side) of a object to be sketched.

2.2 Describe and demonstrate proper technique when sketching.

2.3 Make a sketch from a finished workpiece. (competency D3)

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT IX: BLUEPRINT INTERPRETATION

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plans

  1. Lesson 1: ALPHABET OF LINES
    a. Information outline
    b. Handout
      HO 1.1: Section line cross-hatching
  2. Lesson 2: SKETCHING
    a. Information outline
    b. Job sheet
      JS 2.1: Make a sketch from a finished workpiece

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. Dimensioning and Tolerancing (ANSI Y14.5M). New York: The American Society of Mechanical Engineers, 1982.
2. Geotsch, David L., and John A. Nelson. Technical Drawing and Design. Albany, NY: Delmar Publishers, Inc., 1986.
3. Nickolaisen, Robert. Machine Drafting and Design. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1986.
4. Taylor, David L. Machine Trades Blueprint Reading. Albany, NY: Delmar Publishers, Inc., 1985.
5. Abridged Standards for Engineering Specification 890350, Part I. Armonk, NY: International Business Machines, Inc., 1985.
6. Modern Drafting Practices and Standards Manual. Schenectady, NY: General Electric Company, 1978.

NOTES TO THE INSTRUCTOR

A. Suggested supplemental materials

1. Publications

a. Dimensioning and Tolerancing (ANSI Y14.5M). New York: The American Society of Mechanical Engineers, 1982.

b. Geotsch, David L., and John A. Nelson. Technical Drawing and Design. Albany, NY: Delmar Publishers, Inc., 1986.

c. Nickolaisen, Robert. Machine Drafting and Design. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1986.

d. Taylor, David L. Machine Trades Blueprint Reading. Albany, NY: Delmar Publishers, Inc., 1985.

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT IX: BLUEPRINT INTERPRETATION

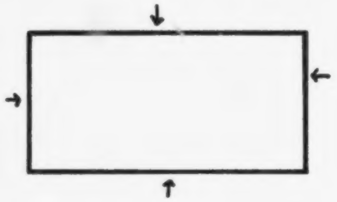
LESSON 1: ALPHABET OF LINES

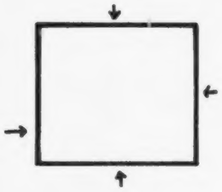
I. Object and hidden lines

A. Object lines

1. Object lines describe the shape of an object on a drawing with heavy lines.

2. An object line is always drawn **heavy and solid** to emphasize the outline or shape of the object.

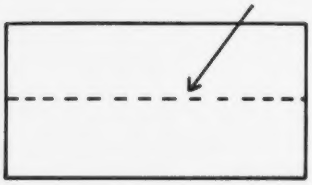


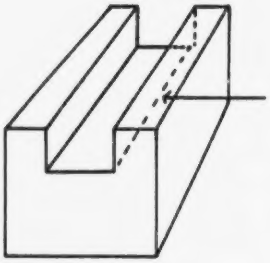


B. Hidden lines

1. To be complete, a drawing must include lines which represent all the edges and intersections of surfaces in the object. Many of these lines are invisible to the observer because they are covered by other portions of the object.

2. To show that a line is hidden, the drafter usually uses a series of **short dashes** to denote "hidden lines".





II. Section lines **(HO 1.1)**

A. As details inside the part become more complex and invisible lines are needed to show the hidden details accurately, the drawing becomes increasingly more difficult to interpret. One technique the drafter uses to simplify such drawings is to cut away a portion of the object and expose the inside surfaces.

B. On such cut-away sections, all of the edges that are visible are represented by visible edge or object lines.

C. Exposed surfaces which have been cut through are further identified by a number of slanted "section" or "cross-hatch" lines.

D. Sectional drawing identification is further simplified by cross-hatch or section lines to readily identify one part from another on a cut-away section.

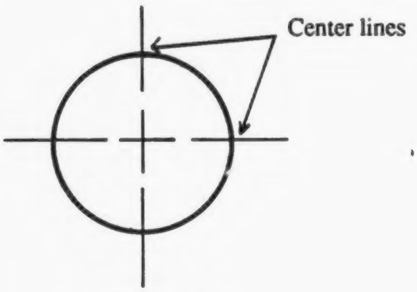
E. Where section lines are used, each combination of lightly drawn, slanted lines refers to a different material. Coss-hatch line combinations are largely standardized and universally used.

III. Center and extension lines

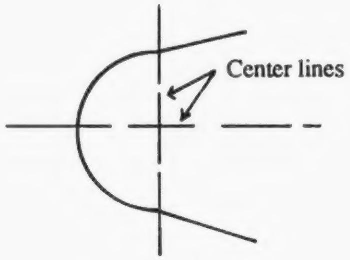
A. Center lines

1. Center lines are drawn as a light broken line of long and short dashes, spaced alternately.

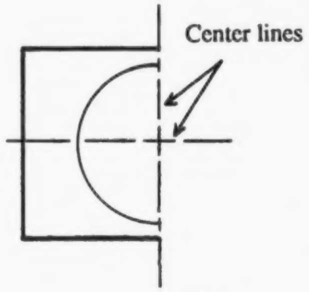
2. Center lines can be used to indicate a circle's part or center and to show when an object is symmetrical.



Whole circles



Parts of a circle

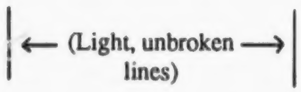


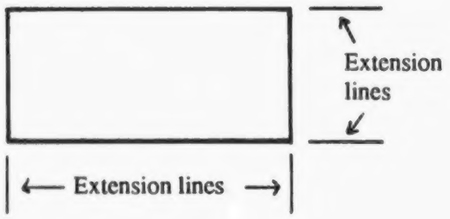
Symmetrical objects

B. Extension lines

1. Extension lines are used in dimensioning to show the size of an object.

2. Extension lines are **light, solid lines** extending away from an object at the exact point where dimensions are to be placed.





3. A 1/16" space is usually allowed between the object and the beginning of the extension line. The extension line usually projects 1/16" beyond a dimension line, as well. Any additional length to the extension is not necessary.

IV. Dimension lines and leaders

A. Dimension lines are **light, solid lines with arrowheads** at the ends. Arrowhead tips or points indicate the exact distance referred to by a dimension.

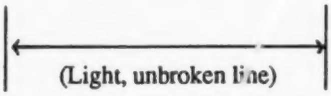
B. The arrowhead point or tip touches the extension line.

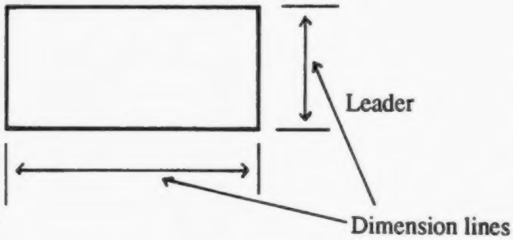
1. The size of the arrow is determined largely by the weight of the dimension line and the size of the drawing.
2. The closed (──▷ ──▶) and open (→) types of arrowheads are the two shapes generally used.

C. According to 1982 ANSI standards, dimension values are put on top of the lines. However, where space is a factor, the dimension value can be placed between arrows by breaking the dimension line.

D. Always use the decimal form of dimensioning on a print unless the tolerance is greater than 1/64".

E. Leaders are **thin lines** used to indicate areas with dimension notes.



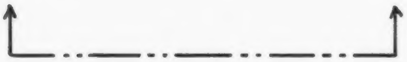


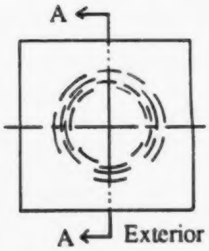
V. Cutting planes

A. The cutting plane line is a **heavy line with one long and two short dashes.**

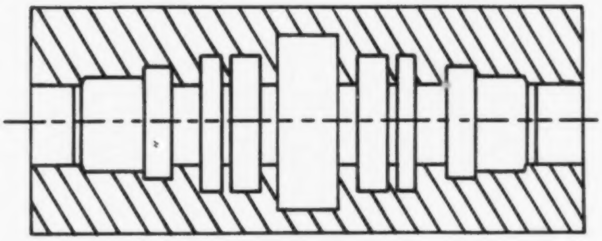
B. The line represents the edge of the cutting plane; arrowheads on the ends of the line show the direction in which the section is viewed.

C. A letter is usually placed near the arrowheads to identify the section.


Cutting plane line



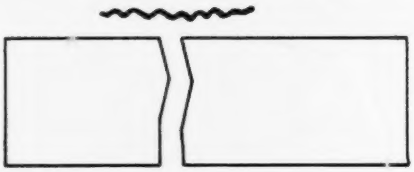
Exterior view


Section A-A
Full section view of interior

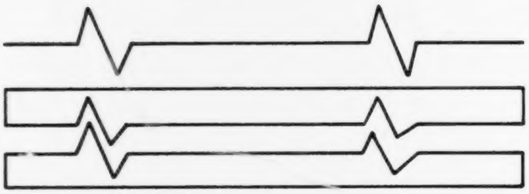
VI. Three types of break lines

A. Break lines detail sections of the part for clarity or show parts which are constant in detail and too long to place on the drawing.

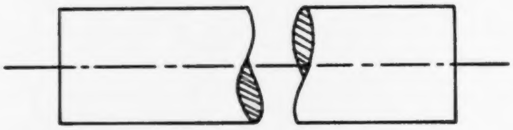
B. When the part to be broken requires a short line, the **thick, wavy, short break line** is used.



C. If the part to be broken is longer, the drafter can use the **thin, long break line**.



D. In round stock such as shafts or pipe, use the **thick "S" break**.



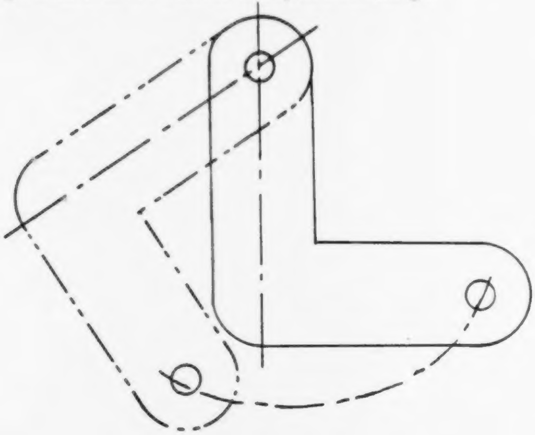
Cylindrical break

VII. Phantom lines

A. Phantom lines are thin lines of long dashes alternating with pairs of short dashes.

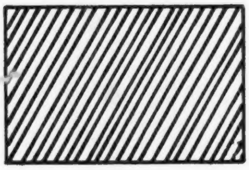
B. There are three purposes for phantom line in drawings.

1. To indicate alternate positions of moving parts, such as a machine arm
2. To show adjacent positions of related parts, i.e. an existing column and repeated detail
3. To indicate datum lines (points or surfaces from which dimensions are measured) in wing and fuselage stations in aircraft blueprint readings

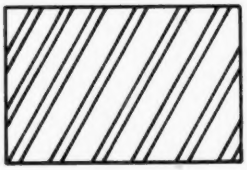


HO 1.1

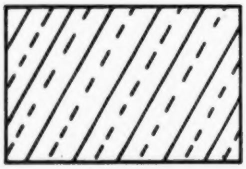
SECTION LINE CROSS-HATCHING



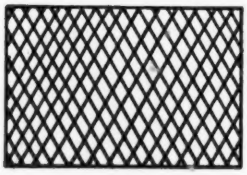
Cast iron



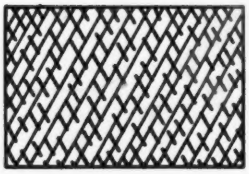
Steel



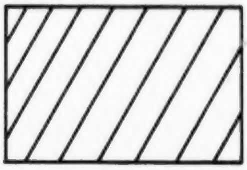
Brass, bronze, copper
and compositions



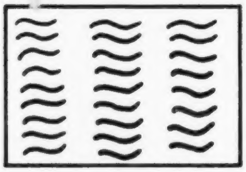
White metal, zinc, lead,
babbit and alloys



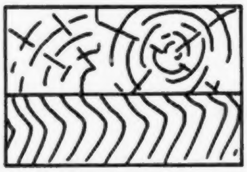
Aluminum and magnesium



Bakelite and plastics



Rubber, felt, leather



Wood

MODULE: MEASUREMENT AND BLUEPRINT READING

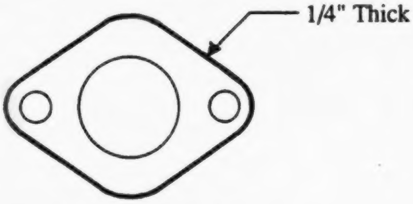
UNIT IX: BLUEPRINT INTERPRETATION

LESSON 2: SKETCHING

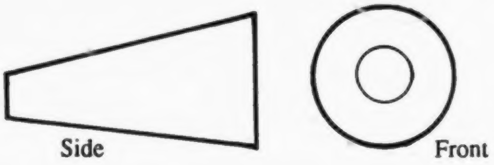
I. Types of sketches

A. **Orthographic** sketching involves 1-6 views, depending on the complexity of the object being drawn. The three views most commonly designated are front, right and top (or plan) sides.

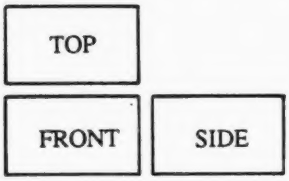
1. One view with a note may be enough for a simple object.



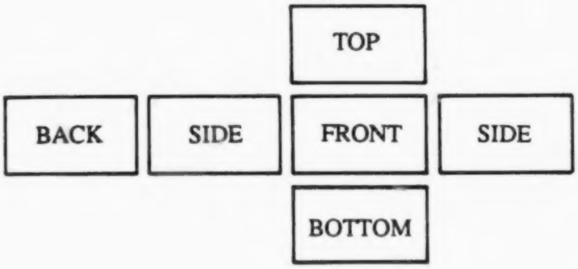
2. Two views are often enough for a round object.



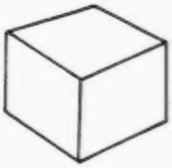
3. Three views is most common.



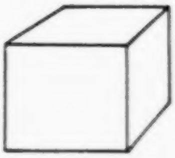
4. The six views should be oriented to each other properly.



B. **Axonometric** sketching is usually an isometric view showing all three sides from one point.



C. Oblique sketching shows front view flat with the paper and the side view receding at an angle (45°).

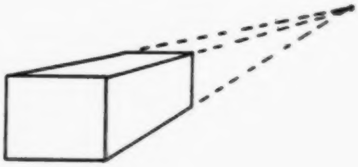


D. Perspective sketching is similar to the way our eyes see an object.

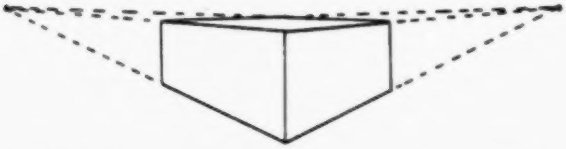
1. Receding lines merge at a "vanishing point."

2. Three variations are possible.

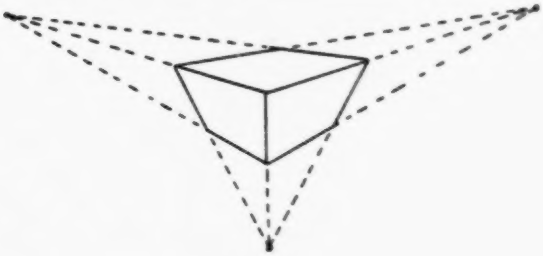
a. One-point perspective has the front view drawn the same as an orthographic projection.



b. Two-point perspective is most often used in architectural drawings.



c. Three-point perspectives are not commonly used. All lines lead to a vanishing point.



II. Sketching technique

A. Straight lines

1. Locate two end points of line.

        2. Move arm from point to point without drawing to check for accuracy of movement.
        3. Sketch horizontal lines with short overlapping strokes from left to right (if left-handed, from right to left).
        4. Sketch vertical lines from top to bottom.
        5. Go over lines again and darken with one continuous line covering the short, dashed lines.
    B. Curves
        1. Locate the arc's center and starting and ending points.
        2. Sketch arc with short overlapping strokes until it looks right.
        3. Go over line again and darken with one continuous line.
        4. It may be easier to lightly sketch a box with an arc or curve and then sketch curve in it.

III. Other guidelines
    A. Proportions need to be estimated as closely as possible so the sketch looks realistic.
    B. Proportion can be estimated by the "unit" method of proportion for length, width and height. (Mark unit on a piece of paper and fashion rule from it.)
    C. Follow ANSI standards as closely as possible for maximum comprehension by others.

MAKE A SKETCH FROM A FINISHED WORKPIECE

Equipment:

1/4" graph paper
Lead pencil (#2 or softer)
Ruler
Micrometer
Vernier caliper
Two workpieces: simple shaft or other round part and a more complex part, as directed by instructor

Procedure:

Simple sketch

1. Secure workpiece and tools.
2. Measure workpiece for sketch dimensioning.
3. Using graph paper, make a two-view orthographic sketch (front and side views) of round part using the correct lines, symbols and freehand sketching techniques covered previously. Add dimensions and explanatory notes as needed.
4. Submit drawing to instructor for evaluation.
5. Make any corrections or additions as suggested by instructor.

Complex sketch

1. Secure more complex part.
2. Measure workpiece for sketch dimensioning.
3. Using graph paper, make a three-view orthographic sketch (front, top and right sides) using the correct lines, symbols and the freehand sketching techniques covered previously. Add dimensions and explanatory notes as needed.
4. Submit drawing to instructor for evaluation.
5. Make any corrections or additions as suggested by instructor.

	Evaluation			
Sketch evaluation (instructor)	3	2	1	N
1. All necessary object and hidden lines present	__	__	__	__
2. Clear and readable	__	__	__	__
3. Correct drawing lines and symbols used	__	__	__	__
4. Quality of lines	__	__	__	__
5. Sketch in reasonable proportions	__	__	__	__
6. Correct dimensioning used	__	__	__	__
7. All necessary dimensions represented	__	__	__	__
Average of above evaluations*	__	__	__	__

*This average is the student's final evaluation for competency D3: Make a sketch from a finished workpiece.

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT IX: BLUEPRINT INTERPRETATION

UNIT TEST

Select the option which answers the question or completes the statement.

____ 1. Which of the following is not a plane of projection in multi-view drawing?

a. Frontal
b. Picture
c. Horizontal
d. Profile
e. Side

____ 2. Where is the horizontal plane be located?

a. Above the object
b. Below the object
c. Behind the object
d. Above or below the object
e. In front of the object

____ 3. Which of the following views does not indicate the height dimension of an object?

a. Top
b. Front
c. Left side
d. Right side
e. Back

____ 4. Where in a note is a leader line located?

a. Above the note
b. Below the note
c. In the middle of the note
d. Before the first word or after the last word of the note
e. Near the side of the note

Choose "a" for true statements and "b" for false ones.

____ 5. A projected surface can appear as either a solid line or hidden line.

____ 6. It is customary to use three or more views for all drawings.

____ 7. A top view is sometimes referred to as a plan view.

____ 8. General notes are used with leader lines to provide information at a certain point on the drawing.

____ 9. Local notes are used to provide specific information at a certain point on the drawing.

____ 10. Notes should be clear, use a minimum of words and have one interpretation.

____ 11. Local notes are found in the title block.

____ 12. Bilateral dimensions are always given as a plus and minus value.

____ 13. Heat treat specifications are always found in the title block.

Select the option which answers the question or completes the statement.

____ 14. The orthographic projection commonly used for a round object as a shaft would have __________ view(s).

a. One
b. Two
c. Three
d. Four
e. Six

____ 15. What is the most common form of axonometric drawing?

a. Oblique
b. Orthographic
c. Isometric
d. Perspective
e. Three view

____ 16. An oblique sketch usually shows the front view flat or parallel to the paper and the lines of the side view receding at __________ degrees.

a. 30
b. 45
c. 60
d. 90
e. 180

____ 17. The most common orthographic projection uses __________ view(s).

a. One
b. Two
c. Three
d. More than three
e. None of the above

____ 18. Which type of drawing most closely duplicates the way the human eye sees an object?

a. Orthographic
b. Axonometric
c. Perspective
d. Oblique
e. Isometric

____ 19. Which type of line is used to show hidden details accurately?

a. Break
b. Center
c. Extension
d. Phantom
e. Section

____ 20. Which type of line is drawn light and broken with long and short dashes spaced alternately?

a. Break
b. Center
c. Extension
d. Phantom
e. Section

____ 21. How much space is usually left between an object and the beginning of an extension line?

a. 1/32"
b. 1/16"
c. 1/8"
d. 1/4"
e. 1/2"

____ 22. Which type of line is shown by a heavy line with one long and two short dashes?

a. Break
b. Cutting plane
c. Extension
d. Phantom
e. Section

____ 23. Which type of line is used to indicate alternate positions of moving parts?

a. Break
b. Cutting plane
c. Extension
d. Phantom
e. Section

____ 24. Break lines used to illustrate cylindrical stock use a __________ line.

a. Thick, wavy, short
b. Thin, long
c. Thick "S"
d. Thick, jagged
e. Thin, circular

____ 25. Which type of line is used to show adjacent positions of related parts, such as an existing column and repeated detail?

a. Break
b. Cutting plane
c. Extension
d. Phantom
e. Section

____ 26. While sketching a straight line, when is the drawing machine's arm moved from point to point to assure movement accuracy?

a. At the beginning of the sketch
b. After locating end points and just before sketching vertical lines
c. During set-up when checking equipment
d. After locating two end points and just before sketching horizontal lines
e. None of the above

ANSWERS TO UNIT TEST (D2)

1. b
2. d
3. a
4. d
5. a
6. b
7. a
8. b
9. a
10. a
11. b
12. b
13. b
14. b
15. c
16. b
17. c
18. c
19. e
20. b
21. b
22. b
23. d
24. c
25. d
26. d

MODULE: MEASUREMENT AND BLUEPRINT READING
UNIT X: TOLERANCES AND ALLOWANCES

UNIT OBJECTIVE

After completion of this unit, the student should be able to demonstrate an understanding of tolerances and allowances as applied to machining plans. This knowledge will be evidenced by achieving the specified score on the unit test.

SPECIFIC OBJECTIVES

Upon completion of the lesson in this unit, the student should be able to:

1.1 Match terms used with tolerances and allowances to corresponding definitions.

1.2 Calculate tolerances and allowances. (competency D4)

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT X: TOLERANCES AND ALLOWANCES

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plans

    1. Lesson 1: TOLERANCES AND ALLOWANCES

        a. Information outline

        b. Assignment sheet

            AS 1.1: Tolerance limits

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. Brown, Walter C. Blueprint Reading for Industry. South Holland, IL: The Goodheart-Willcox Company, 1976.

2. Brown, Walter C. Drafting for Industry. South Holland, IL: The Goodheart-Willcox Company, 1984.

3. French, Thomas, et. al. Mechanical Drawing. 10th ed. New York: McGraw-Hill Book Co., 1985.

4. Taylor, David L. Machine Trades Blueprint Reading. Albany, NY: Delmar Publishers, Inc., 1985.

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT X: TOLERANCES AND ALLOWANCES

LESSON 1: TOLERANCES AND ALLOWANCES

NOTE: The purpose of tolerances and allowances is to allow acceptable variation in part sizes while still retaining enough accuracy for proper fits of parts to each other.

I. Terms and definitions

- A. Actual size--the size as accurately measured
- B. Nominal size--general classification of commercial product (such as 1/2" black iron pipes actually .622" inside diameter and .840" outside diameter
- C. Basic size--the general size required for necessary designs, fits or strength (specified with allowance tolerances on plans)
- D. Allowance--acceptable differences in part sizes or hole sizes between limits of maximum and minimum sized
- E. Design size--size of part measurement after clearance allowances have been applied
- F. Limits--maximum and minimum sizes after the tolerances have been specified in the design
- G. Tolerance--total acceptable variation allowed (difference between the maximum and minimum limits)
- H. Unilateral tolerance--dimension differences acceptable only one direction from design size
- I. Bilateral tolerance--dimension differences acceptable both directions from design size
- J. Datum--points, lines, surfaces or planes assumed to be accurate and used as reference points from which to set other dimensions

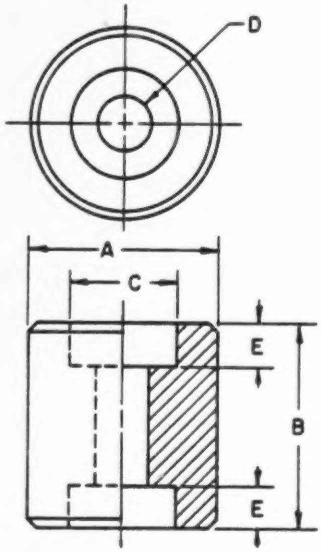
II. Dimension and tolerances information

- A. Linear dimensions
  1. Specified in inches up to 72"
  2. Specified in inches and feet over 72"
  3. May be indicated in decimals or fractions
- B. Angular dimensions given in degrees (°), minutes(') and seconds (")
- C. Reference dimensions
  1. Not used for layout of parts
  2. Used for reference and checking
  3. No tolerance applied to reference dimensions

D. Tabular dimensions

1. Used to simplify drawings
2. Dimensions arranged in chart or table form
3. Letters added to drawings to indicate corresponding dimension on chart

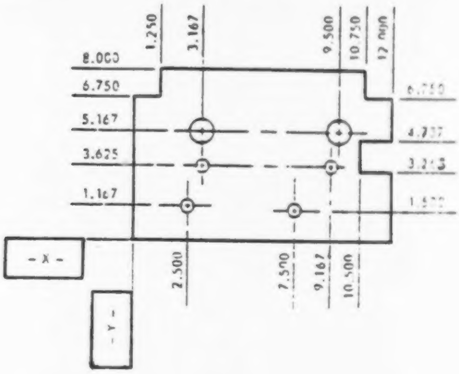
BUSHING					
PART NO.	A	B	C	D	E
CB 1	1.500	2.000	1.000	0.500	0.375
CB 2	1.625	2.125	1.125	0.625	0.437
CB 3	1.750	2.250	1.250	0.750	0.500
CB 4	1.875	2.375	1.375	0.875	0.562
CB 5	2.000	2.500	1.500	1.000	0.625



Credit: French, Thomas, et. al. Mechanical Drawing. 10th ed. New York: McGraw-Hill Book Co., © 1985, pg. 251. Reproduced with permission.

E. Arrowless dimensions

1. Used on complex drawings to improve ease of reading
2. Eliminates need for all extension and dimension lines
3. Sometimes designated as datum or coordinate dimensions



Credit: Brown, Walter C. Blueprint Reading for Industry. South Holland, IL: The Goodheart-Willcox Company, 1976. Reproduced with permission.

TOLERANCE LIMITS

Using the dimensions specified to the left of the chart, calculate permissible sizes (maximum and minimum) and acceptable allowances.

		Maximum permissible size	Minimum permissible size	Acceptable allowance
1.	1.300 ±.050			
2.	1.300 +.005 -.000			
3.	1.300 ±.000			
4.	1.300 +.000 -.055			
5.	1.300 +.010			
6.	1.300 +.005 -.010			

ANSWERS TO ASSIGNMENT SHEET

		Maximum permissible size	Minimum permissible size	Acceptable allowance
1.	1.300 ±.050	1.350	1.250	0.100
2.	1.300 +.005 -.000	1.305	1.300	0.005
3.	1.300 ±.000	1.300	1.300	0.000
4.	1.300 +.000 -.055	1.300	1.245	0.055
5.	1.300 +.010	1.310	1.300	0.010
6.	1.300 +.005 -.010	1.305	1.290	0.015

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT X: TOLERANCES AND ALLOWANCES

UNIT TEST

Match the following terms and definitions.

____ 1. General classification of a commercial product

____ 2. General size required for necessary designs, fits or strength

____ 3. Acceptable differences in part sizes or hole sizes between the limits of maximum and minimum sizes

____ 4. Size of a part measurement after clearance allowances have been applied

____ 5. Maximum and minimum sizes allowable after tolerances have been specified

____ 6. Total allowance variation allowed

____ 7. Dimension differences acceptable only one direction from design size

____ 8. Dimension differences acceptable both directions from design size

____ 9. Points, lines, surfaces or planes used as reference points

a. Actual size
b. Allowance
c. Basic size
d. Bilateral tolerance
e. Datum
ab. Design size
ac. Limits
ad. Nominal size
ae. Tolerance
bc. Unilateral tolerance

Select the option which best answers the question or completes the statement.

____ 10. If a tolerance is specified as 1.375 ±.005, what is the maximum permissible size?

a. 1.325
b. 1.370
c. 1.375
d. 1.380
e. 1.425

____ 11. If a tolerance is specified as 1.375 ±.005, what the minimum permissible size?

a. 1.325
b. 3.370
c. 1.375
d. 1.380
e. 1.425

____ 12. If a tolerance is specified as $3.529 \begin{smallmatrix} +.000 \\ -.050, \end{smallmatrix}$ what is the maximum permissible size?

a. 3.479
b. 3.524
c. 3.529
d. 3.534
e. 3.579

____ 13. If a tolerance is specified as 3.529 $^{+.000}_{-.050,}$ what is the minimum permissible size?

a. 3.479
b. 3.524
c. 3.529
d. 3.534
e. 3.579

____ 14. If a tolerance is specified as 6.115 $^{+.02}_{-.00,}$ what is the minimum permissible size?

a. 6.095
b. 6.113
c. 6.115
d. 6.117
e. 6.135

____ 15. If a tolerance is specified as 6.115 $^{+.02}_{-.00,}$ what is the maximum permissible size?

a. 6.095
b. 6.113
c. 6.115
d. 6.117
e. 6.135

____ 16. If a tolerance is specified as 9.835 +.01, what is the minimum permissible size?

a. 9.825
b. 9.834
c. 9.835
d. 9.836
e. 9.845

____ 17. If a tolerance is specified as 9.835 +.01, what is the maximum permissible size?

a. 9.825
b. 9.834
c. 9.835
d. 9.836
e. 9.845

ANSWERS TO TEST (D4)

1. ad
2. c
3. b
4. ab
5. ac
6. ae
7. bc
8. d
9. e
10. d
11. b
12. c
13. a
14. c
15. e
16. c
17. e

MODULE: MEASUREMENT AND BLUEPRINT READING
UNIT XI: GEOMETRIC DIMENSIONING AND TOLERANCING

UNIT OBJECTIVE

Upon completion of this unit, the student should be able to demonstrate an understanding of geometric dimensioning and tolerancing and be able to interpret it on machining plans. This knowledge will be evidenced by achieving the specified scores on the unit test.

SPECIFIC OBJECTIVES

Upon completion of the lesson in this unit, the student should be able to:

1.1 Match blueprint symbols and meanings commonly utilized in geometric dimensioning and tolerancing.

1.2 Describe tolerance for form characteristics.

1.3 Describe tolerance for profile applications.

1.4 Describe uses of tolerance for orientation.

1.5 Describe uses of tolerance for location.

1.6 Describe tolerance for run-out applications.

1.7 Interpret feature control call-outs as used on machine blueprints. (competency D6)

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT XI: GEOMETRIC DIMENSIONING AND TOLERANCING

CONTENTS OF THIS UNIT

A. Objective

B. References

C. Notes to the instructor

D. Lesson plan

  1. Lesson 1: DIMENSIONING AND TOLERANCING

    a. Information outline

    b. Handouts

      HO 1.1: Symbols and abbreviations
      HO 1.2: Feature control frame

    c. Assignment sheet

      AS 1.1: Terms and definitions

    d. Answers to assignment sheet

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. Dimensioning and Tolerancing (ANSI Y14.5M). New York: The American Society of Mechanical Engineers, 1982.

2. Brown, Walter C. Blueprint Reading for Industry. South Holland, IL: The Goodheart-Willcox Company, 1976.

3. Brown, Walter C. Drafting for Industry. South Holland, IL: The Goodheart-Willcox Company, 1984.

4. French, Thomas, et. al. Mechanical Drawing. 10th ed. New York: McGraw-Hill Book Co., 1985.

5. Geotsch, David L., and John A. Nelson. Technical Drawing and Design. Albany, NY: Delmar Publishers, Inc., 1986.

6. Taylor, David L. Machine Trades Blueprint Reading. Albany, NY: Delmar Publishers, Inc., 1985.

B. Pamphlets/course syllabi

1. A Pocket Guide to Geometric Dimensioning and Tolerances. Hillsboro, MO: Jefferson College, 1986.

2. Hevel, David, and William Daniel. Geometric Dimensioning and Tolerancing. Hannibal, MO: Hannibal Area Vocational Technical School, 1986.

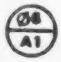
MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT XI: GEOMETRIC DIMENSIONING AND TOLERANCING

LESSON 1: DIMENSIONING AND TOLERANCING

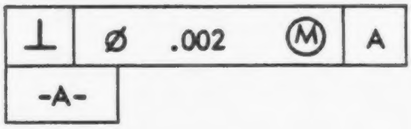
I. Terms and definitions (HO 1.1)

- A. Maximum material condition
    1. Also shown as "MMC" or Ⓜ
    2. Condition where most material possible remains after matching to specified allowable tolerances
    3. Translates into largest acceptable shaft or smallest acceptable hole
- B. Least material condition
    1. Also shown as "LMC" or Ⓛ
    2. Condition where smallest amount of material acceptable remains after machining to specified allowable tolerances
    3. Translates into smallest acceptable shaft of piece of material and largest acceptable hole
- C. Datum plane `-letter-`
    1. Primary datum--plane made by three or more high points of object; prevents object from rocking
    2. Secondary datum--plane perpendicular to primary datum which passes through two or more high points of object; prevents object from rocking
    3. Tertiary datum--plane perpendicular to primary and secondary datum planes that makes at least one contact point with object
    4. Datum axis--intersection of two or more perpendicular datum planes
    5. Datum targets--specific points or lines used to establish references points in irregular surfaces such as on castings (designated by "X" on plan)
    6. Call-out--circle with line through it and letter or number in bottom half to tell which datum targets are indicated



- D. Feature--generalized term meaning some surface, shaft, hole, slot or other physical part of an object

E. Feature control frame/modifying symbols--used to designate differences from perfect size and usually placed before or after tolerances to determine special controls **(HO 1.2)**



NOTE: Several aspects of machining are toleranced. They are form, profile, orientation, location and run-out. Each is discussed in more detail as follows.

II. Tolerance of form

- A. Used to control object's shape with zones of tolerance
- B. Virtual condition--limit due to the collective effect of maximum material condition, MMC, combined with acceptable tolerances
- C. Applications
    - 1. Straightness--zone within which a material's axis or surface must stay
    - 2. Flatness--zone within which all elements in a plane must stay
    - 3. Roundness or circularity--zone created between two concentric circles established at maximum and minimum acceptable distances from an established central axis
    - 4. Cylindricity--extension of circularity concept in which all elements fall within a zone of tolerance call-out. Spherical parts are excluded from this tolerance.

III. Tolerance for profile

- A. Used to control variations in surface profile
- B. Provides boundaries along true profile within which all elements of specified surface must stay
- C. Used for objects with irregular form (die-castings) or objects with interacting irregular shapes
- D. Types of profile tolerancing
    - 1. Bilateral--allows surface to deviate within tolerance on both sides of true contour
    - 2. Unilateral--allows surface to deviate within tolerance on either, but only one, side of true contour
    - 3. All round--allows deviations of surface within tolerance across entire surface or to a line element all around an object's boundary
- E. Tolerancing for profile to a line--used to set tolerance range around a two-dimensional line
- F. Tolerancing for profile to a surface--used to set tolerance range to entire surface of object
- G. Combined tolerance for profile--used with other call-outs to more closely specify acceptable variation of object

IV. Tolerance for orientation

A. Used to relate and control relationship of one feature to another or to a datum plane

B. Also called "attitude tolerance"

C. Types of tolerance for orientation

1. Angularity--establishes a tolerance zone within which all surface features or axis features must lay at a specified angle (other than 90°)

2. Perpendicularity

a. Establishes a tolerance zone of acceptable deviation of right angles to a datum plane or axis

b. May be used to control planes or axis, cylindrical and line elements

3. Parallelism

a. Feature control which relates acceptable tolerance of parallelism from one plane or axis to another

b. Stated as plane to plane, plane to axis or axis to axis

V. Tolerance for location

A. Relates features of position or concentricity to datum or another feature

B. Location of features based on other features or datum reference planes

C. Location tolerance for concentricity and symmetry is used with RFS tolerance and references feature axis (regardless of feature size) to common datum axis or datum axis counterpart

VI. Tolerance for run-out

A. References feature deviation from perpendicularity or parallelism to datum axis

B. Types

1. Circular run-out

a. Symbol ↗

b. References acceptable deviation when feature is rotated around the specified datum plane

c. Similar to concept of circularity

d. Tolerance specified is total tolerance or "full indicator movement" (FIM)

2. Right angle run-out

3. Total run-out

a. Symbol ⌰

    b. References cumulative or composite variations of circularity, straightness, angularity, taper, coaxiality or profile at same time while object is completely rotated

VII. Reading plans with geometric dimensioning and tolerancing

  A. Locate all datums.

  B. Locate all basic or untoleranced dimensions.

  C. Locate all feature controls relating to a datum.

  D. Locate all feature controls relating only to features.

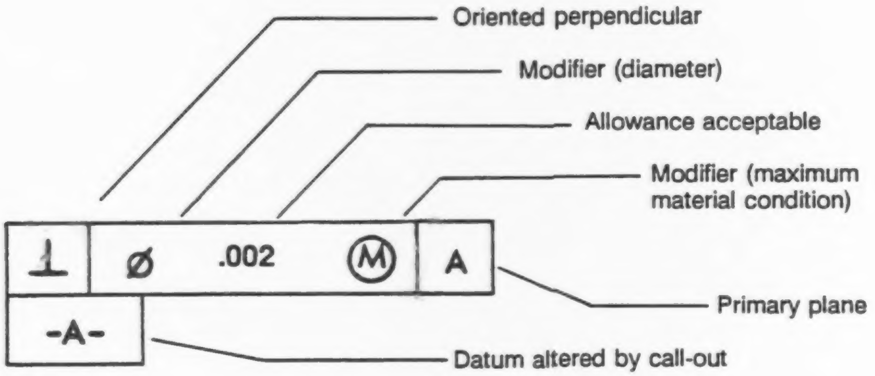
  E. Locate all features with multiple feature controls.

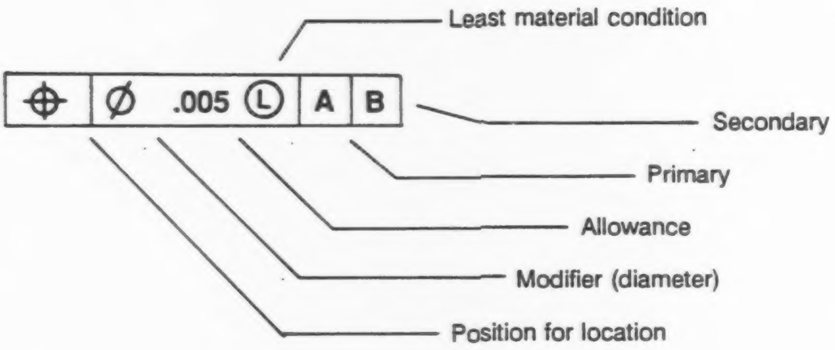
HO 1.1

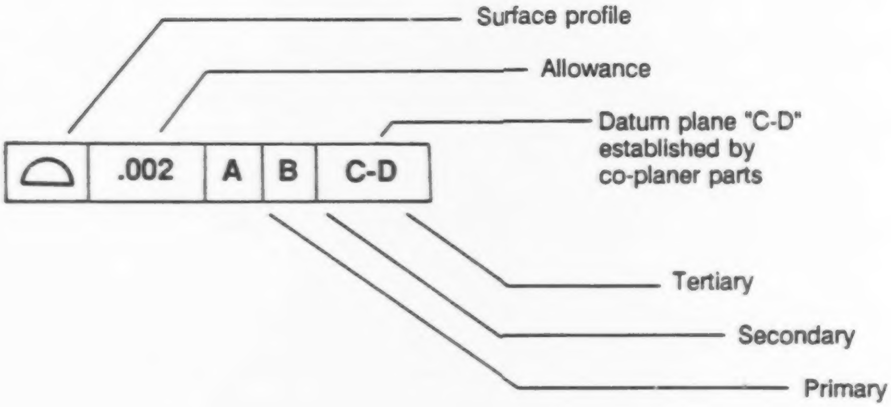
SYMBOLS AND ABBREVIATIONS
(from ANSI standard Y14.5M-1982)

Symbol	Meaning	Symbol	Meaning
✕	Datum target	⌓	Profile of a surface
⊖	Call-out	∠	Angularity
Ⓜ	Maximum material condition	⊥	Perpendicularity
Ⓛ	Least material condition	//	Parallelism
Ⓢ	Regardless of feature size	⌖	Position
Ⓟ	Projected tolerance zone	◎	Concentricity
Ø	Diameter	↗	Run-out--Circular
SØ	Spherical diameter	⌰	Run-out--Total
R	Radius	⌱	Dimension origin
SR	Spherical radius	⌲	Conical taper
(50)	Reference	⌳	Slope
$\overset{\frown}{105}$	Arc length	⌴	Spotface or counterbore
—	Straightness	⌵	Countersink
⌭	Cylindricity	↧	Deep or depth
⏥	Flatness	□	Square
○	Circularity	$\underline{15}$	Dimension not to scale
⌒	Profile of a line	8X	Number of places or times

FEATURE CONTROL FRAMES







TERMS AND DEFINITIONS

For each term below, select the best definition to match it.

____ 1. Tells which datum targets are indicated

____ 2. Intersection of two or more perpendicular datum planes

____ 3. Specific points designated by "X"

____ 4. Physical part of object

____ 5. Smallest amount of possible material

____ 6. Most possible material remaining

____ 7. Plane made by at least three points of object

____ 8. Plane perpendicular to primary datum and passing through at least two points

____ 9. Plane perpendicular to primary and secondary datums

____ 10. Controls shape within zones of tolerance

____ 11. Controls concentricity of features

____ 12. Controls relationship of one feature to another

____ 13. Controls variations in surface

____ 14. Controls deviation from perpendicularity

____ 15. Collective limit due to tolerance and maximum material condition

a. Maximum material condition

b. Least material condition

c. Primary datum

d. Secondary datum

e. Tertiary datum

ab. Datum axis

ac. Datum target

ad. Call-out

ae. Feature

bc. Tolerance for form

bd. Tolerance for profile

be. Virtual condition

cd. Tolerance for orientation

ce. Tolerance for run-out

de. Tolerance for location

ANSWERS TO ASSIGNMENT SHEET

1. ad
2. ab
3. ac
4. ae
5. b
6. a
7. c
8. d
9. e
10. bc
11. de
12. cd
13. bd
14. ce
15. be

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT XI: GEOMETRIC DIMENSIONING AND TOLERANCING

UNIT TEST

Mark true statements with an "a" and false ones with a "b".

____ 1. The intersection of two or more datum planes is called the datum target.

____ 2. A tertiary datum plane needs only one point of contact with the object.

____ 3. A primary datum plane needs only two or points in contact with the object.

____ 4. "MMC" means "Marginal material condition".

____ 5. The symbol for circular run-out is ↗.

Match the following terms to definitions.

____ 6. Controls shape within zones of tolerance

____ 7. Controls concentricity of features

____ 8. Controls relationship of one feature to another

____ 9. Controls variations in surface

____ 10. Controls deviation from perpendicularity or parallelism to datum axis

a. Tolerance for form

b. Tolerance for profile

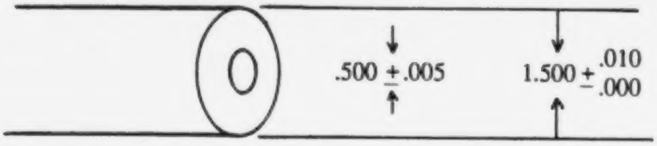
c. Collective limit

d. Tolerance for orientation

e. Tolerance for run-out

ab. Tolerance for location

For each item below, refer to illustration and provide the correct answer from the list on the right.



____ 11. Ⓜ of the indicated hole

____ 12. Ⓛ of the indicated hole

____ 13. Ⓜ of the outside diameter

____ 14. Ⓛ of the outside diameter

a. 0.495

b. 0.500

c. 0.505

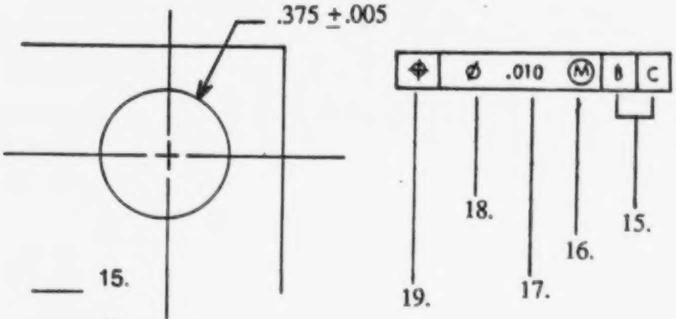
d. 1.490

e. 1.500

ab. 1.505

ac. 1.510

Using the control frame illustrated, match the symbol with its meaning.



____ 15.

____ 16.

____ 17.

____ 18.

____ 19.

a. Circularity

b. Curve

c. Datums

d. Diameter

e. Maximum material condition

ab. Minimum material condition

ac. Position

ad. Radius

ae. Straightness

bc. Tolerance

For each symbol below, match its meaning with the terms in the right column.

___ 20. ⏥
___ 21. ○
___ 22. —
___ 23. ⊥
___ 24. ∠
___ 25. //

a. Angularity
b. Concentricity
c. Circularity
d. Flatness
e. Parallelism
ab. Run-out
ac. Straightness
ad. Perpendicularity

- -

___ 26. ↗
___ 27. ⌖
___ 28. ⌰
___ 29. ◎
___ 30. Ø
___ 31. ⌭

a. Circular run-out
b. Concentricity
c. Cylindricity
d. Diameter
e. Parallelism
ab. Position
ac. Spherical run-out
ad. Total run-out

ANSWERS TO TEST (D6)

1. b
2. a
3. b
4. b
5. a
6. a
7. ab
8. d
9. b
10. e
11. a
12. c
13. ac
14. e
15. c
16. e
17. bc
18. d
19. ac
20. d
21. c
22. ac
23. ad
24. a
25. e
26. b
27. ab
28. ad
29. c
30. d
31. a

MODULE: MEASUREMENT AND BLUEPRINT READING
UNIT XII: PART LAYOUT AND MACHINING SEQUENCE

UNIT OBJECTIVE

Upon completion of this unit, the student should show an understanding of plans, their dimensions and their influence on part layout. The student should also be able to demonstrate an understanding of acceptable sequencing of machining operations by utilizing the Machinery's Handbook. This knowledge will be evidenced by achieving the specified score on the unit test.

SPECIFIC OBJECTIVES

Upon completion of the lessons in this unit, the student should be able to:

1.1 Interpret a part plan as to line usage, necessary dimensions and missing dimensions. (competency D5, AS 1.1)

1.2 Calculate missing dimensions. (competency D5)

2.1 Use Machinery's Handbook to plan work. (competency D7)

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT XII: PART LAYOUT AND MACHINING SEQUENCE

CONTENTS OF THIS UNIT

A. Objective sheet

B. References

C. Notes to the instructor

D. Lesson plans

  1. Lesson 1: PART LAYOUT

    a. Handout

      HO 1.1: Print sample

    b. Assignment sheet

      AS 1.1: Part layout

  2. Lesson 2: MACHINING SEQUENCE

    a. Information outline

    b. Assignment sheet

      AS 2.1: Machinery's Handbook practice

E. Unit test

F. Answers to unit test

REFERENCES

A. Books

1. Brown, Walter C. Blueprint Reading for Industry. South Holland, IL: The Goodheart-Willcox Company, 1976.

2. Brown, Walter C. Drafting for Industry. South Holland, IL: The Goodheart-Willcox Company, 1984.

3. Geotsch, David L., and John A. Nelson. Technical Drawing and Design. Albany, NY: Delmar Publishers, Inc., 1986.

4. Nickolaisen, Robert. Machine Drafting and Design. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1986.

5. Oberg, Erik; Franklin D. Jones; Holbrook L. Horton. Machinery's Handbook. 23rd ed. New York: Industrial Press Inc., 1988.

NOTES TO THE INSTRUCTOR

A. Suggested approaches to teaching this unit

1. Plans can be selected by instructor from books listed in the references or any other drafting or machining source with plans.

2. After securing a plan from the instructor and studying it, the student can practice laying out the part's lines on a sheet of drawing paper, vellum or hardboard. Evaluate students' proficiency by having them lay out a part on a piece of sheet metal, actual stock or machineable wax. (competency **D8**)

3. Competency **D9**: Plan sequence of machining operations is addressed in the Lathe module, Unit VI.

B. Suggested student activities

1. For this unit, students may need to review information presented for the following competencies: C5-7, C16, C21, D1, D4, D5.

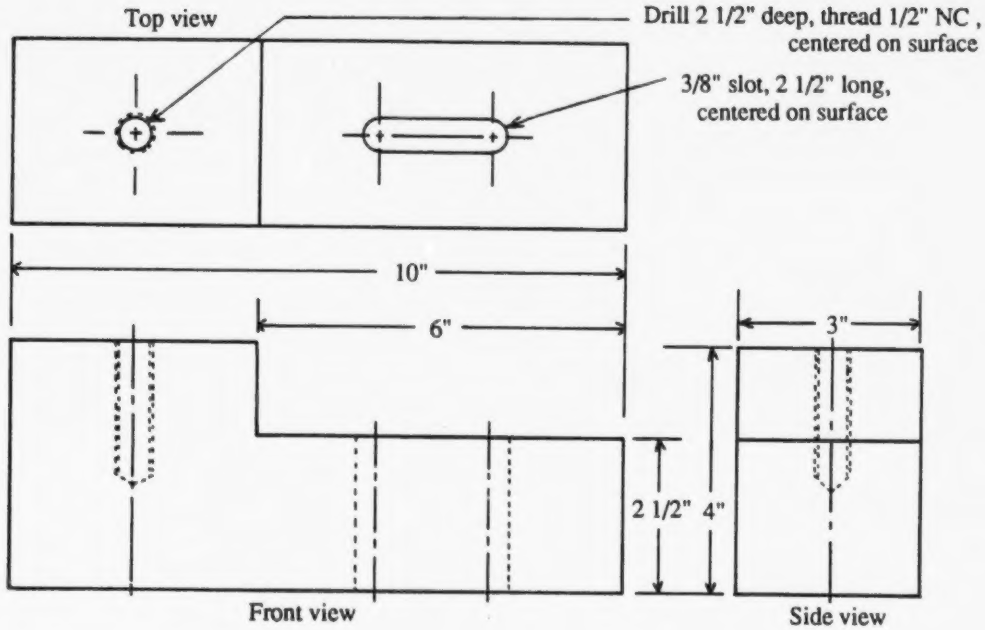
2. Student should review plans of varying difficulty showing possible layout of necessary points and lines.

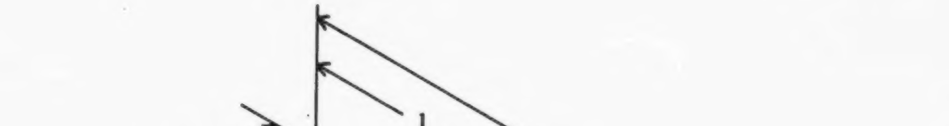
C. Suggested supplemental materials

1. Oberg, Erik; Franklin D. Jones; Holbrook L. Horton. Machinery's Handbook. 23rd ed. New York: Industrial Press Inc., 1988.

2. Location and Positioning of Datum Surfaces Using the Vertical Milling Machine (MS-86-364) (video). Sedalia, MO: State Fair Community College, 1986. (Available for purchase from SFCC; available for loan from Missouri Vocational Resource Center, phone 800/392-7217 or 314/882-9610)

PRINT SAMPLE





AS 1.1

PART LAYOUT

For the questions below, use HO 1.1 as the plan. According to the three-view drawing of the step block, determine dimensions shown on the isometric view.

1. What is the size of dimension 1? __________
2. What is the size of dimension 2? __________
3. What is the size of dimension 3? __________
4. What is the size of dimension 4? __________
5. What is the size of dimension 5? __________
6. What is the size of dimension 6? __________
7. What is the size of dimension 7? __________
8. What is the size of dimension 8? __________
9. What is the size of dimension 9? __________
10. What is the size of dimension 10? __________
11. What is the depth of the slot? __________
12. What is the depth of the threaded hole? __________
13. What is the overall length of the slot? __________

ANSWERS TO AS 1.1

1. 4"
2. 6"
3. 10"
4. 4"
5. 3"
6. 1.5"
7. 3"
8. 2 1/8"
9. 2"
10. 1 1/2"
11. 2 1/2"
12. 2 1/2"
13. 2 1/2"

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT VI: PART LAYOUT AND MACHINING SEQUENCE

LESSON 2: MACHINING SEQUENCE

I. The Machinery's Handbook has a vast amount of machining information, which is presented largely in table form. A machinist should become familiar with the location of information in the Machinery's Handbook.

- A. Ready references index on inside front and back covers
- B. General contents
    1. 22nd ed.: begins on page xi
    2. 23rd ed.: begins on page vii
- C. Comprehensive index
    1. 22nd ed.: starts on page 2447
    2. 23rd ed.: starts on page 2449
- D. Special metric index
    1. 22nd ed.: begins on page 2509
    2. 23rd ed.: included with comprehensive index

MACHINERY'S HANDBOOK PRACTICE

For each question below, use the Machinery's Handbook (22nd-23rd editions) to locate the correct answer. Give the answer and the page found.

1. What is the length of the cutting flutes of a 7/16" ANSI regular length multiple-flute medium helix, single end milling cutter with a Weldon shank?

   length ____________ page ____________

2. What mathematical formula should be used to solve the length of a side of a right-angle triangle if the other two sides are known?

   formula ____________ page ____________

3. What would be the standard taper per foot of a No. 3 Morse standard taper shank?

   taper ____________ page ____________

4. What is the recommended cutting speed in feet per minute for turning 1020 plain carbon steel with a high-speed steel cutter?

   speed ____________ page ____________

5. What is the recommended cutting speed in feet per minute for turning 1020 plain carbon steel with a carbide cutter?

   speed ____________ page ____________

6. What is the mathematical conversion to decimal equivalence of 13/64"?

   decimal ____________ page ____________

7. What is the mathematical conversion into millimeters of 13/64"?

   decimal ____________ page ____________

8. What would be the manufacturers' standard thickness in decimal inches of a 20-gauge steel sheet?

   thickness ____________ page ____________

9. What is the recommended cutting speed in feet per minute of a high-speed steel cutter for turning or milling aluminum sand mold casting alloy (untreated)?

   speed ____________ page ____________

10. What is the recommended cutting speed in feet per minute of a carbide cutter for turning or milling of aluminum sand mold casting alloy (untreated)?

    speed ____________ page ____________

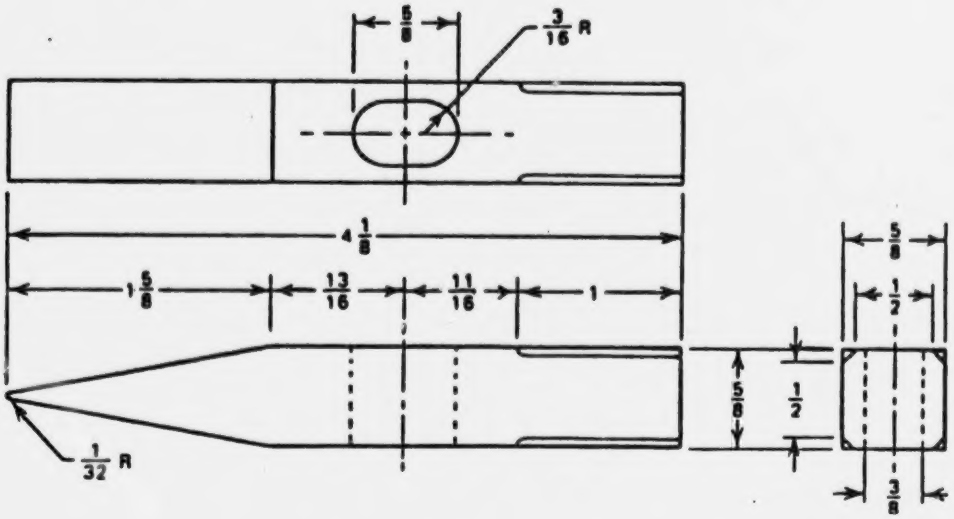
ANSWERS TO AS 2.1

		Pg. no.	
		22nd ed.	23rd ed.
1.	1"	1600	769
2.	$c = \surd a^2 + b^2$	8277	
3.	.60235	1735	898
4.	90	1767	975
5.	350	1767	975
6.	0.203125	1	2410
7.	5.1594	1	2430
8.	0.359	357	416
9.	750	1773	981
10.	1400	1773	981

MODULE: MEASUREMENT AND BLUEPRINT READING

UNIT XII: PART LAYOUT AND MACHINING SEQUENCE

UNIT TEST



Answer the following according to the above three-view hammer head drawing.

____ 1. What minimum sized stock is needed to make the hammer head?

a. 1/2" x 1/2" x 4 1/2"
b. 5/8" x 5/8" x 4 1/2"
c. 5/8" x 5/8" x 4 5/8"
d. 3/4" x 3/4" x 4 3/4"
e. 3/4" x 3/4" x 4 7/8"

____ 2. What drill bit or milling cutter diameter size would be used to open up the hole for the handle?

a. 3/8"
b. 1/2"
c. 5/8"
d. 3/4"
e. 7/8"

____ 3. How long is the tapered portion of the head?

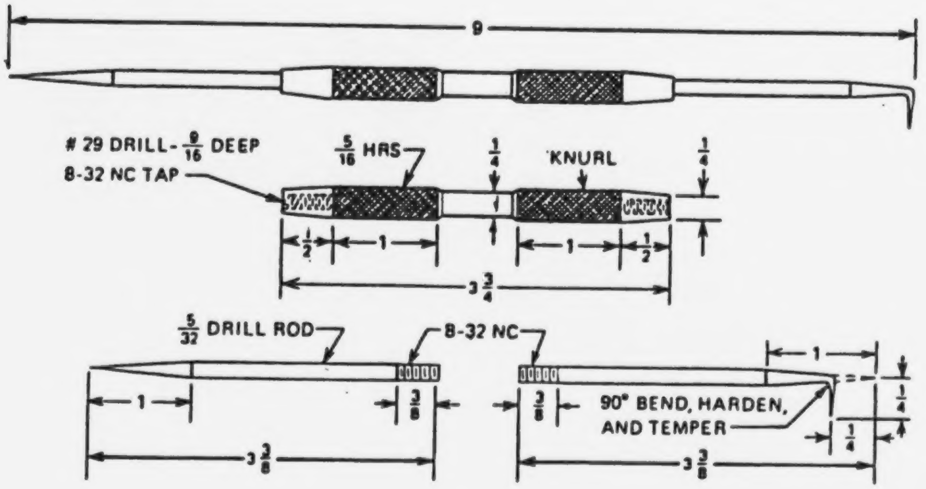
a. 1 3/8"
b. 1 1/2"
c. 1 5/8"
d. 1 3/4"
e. 1 7/8"

____ 4. How far from the front (flat) of the head is the center of the handle hole?

a. 9/16"
b. 5/8"
c. 11/16"
d. 3/4"
e. 13/16"

____ 5. How far from each end would the exact center of the hammer head lie?

a. 1 7/8"
b. 1 15/16"
c. 2"
d. 2 1/16"
e. 2 1/8"



Use the above scriber plan to answer the questions below.

____ 6. How far into the body center will each end screw?

a. 5/16"
b. 3/8"
c. 1/4"
d. 1/2"
e. 3/4"

____ 7. What size of threads are on the ends of the body center?

a. 3-34 NC
b. 8-32 NC
c. 8-32 TAP
d. 3/8"
e. 1/2"

____ 8. How much of each end is tapered?

a. 1/4"
b. 3/8"
c. 1/2"
d. 3/4"
e. 1"

____ 9. What is done to the body to make it easier to grip?

a. Chamfering
b. Tempering
c. Knurling
d. Polishing
e. Coating

____ 10. What material is used for the ends?

a. Hot rolled steel
b. Drill rod
c. Aluminum
d. Cold rolled steel
e. Brass

____ 11. What material is used for the body center?

a. Hot rolled steel
b. Drill rod
c. Aluminum
d. Cold rolled steel
e. Brass

____ 12. How deep are holes drilled before threading?

a. 1/4"
b. 29 mm
c. 1/2"
d. 9/16"
e. 9/32"

____ 13. How long will the assembled tool be when finished?

a. 9"
b. 8"
c. 5 3/4"
d. 5"
e. 3 3/8"

____ 14. What drill bit diameter size would be used for the tap hole for the threads to receive the 5/32" rods?

a. 9/16"
b. 8-32
c. #9
d. #20
e. #29

____ 15. What is the maximum diameter of the body before the finishing process?

a. 3/4"
b. 5/16"
c. 1/2"
d. 3/8"
e. 1/4"

Using the Machinery's Handbook as a reference, answer the following.

____ 16. What would be the decimal equivalent in inches diameter of a 12.80 mm straight-shank twist drill bit?

a. 0.0320
b. 0.5039
c. 0.830
d. 1.386
e. 1.484

____ 17. What is the recommended rpm for a letter "F" twist drill bit at a cutting speed of 100 feet per minute?

a. 1200
b. 1315
c. 1390
d. 1486
e. 1584

____ 18. What would be the thickness in inches of Brown & Sharpe Gauge no. 20 copper (non-ferrous)?

a. 0.0320
b. 0.5039
c. 0.830
d. 1.386
e. 1.484

____ 19. What would be the approximate weight in pounds of a square foot of Brown & Sharpe Gauge no. 20 copper (non-ferrous)?

a. 0.0320
b. 0.5039
c. 0.830
d. 1.386
e. 1.484

____ 20. What would be the body diameter in millimeters of a no. 4 plain type ANSE combination drill and countersink?

a. 0.35
b. 3.985
c. 7.94
d. 8.34
e. 9.015

____ 21. What would be the coefficient of static friction for steel on clean phosphor bronze?

a. 0.35
b. 3.985
c. 7.94
d. 8.34
e. 9.015

____ 22. What would be the coefficient of static friction for steel on clean brass?

a. 0.35
b. 3.985
c. 7.94
d. 8.34
e. 9.015

____ 23. What is the minimum diameter of a 4" ANSI metal-slitting saw?

a. 0.35
b. 3.985
c. 7.94
d. 8.34
e. 9.015

____ 24. What is the recommended cutting speed in feet per minute for milling of plain 1020 carbon steel with Brinell hardness of 200 using a high-speed steel cutter?

a. 90
b. 254
c. 500
d. 807
e. 911

____ 25. What is the recommended cutting speed in feet per minute for drilling of aluminum sand mold casting alloy as cast?

a. 90
b. 254
c. 500
d. 807
e. 911

____ 26. What is the recommended rpm of a 3" diameter cutter which needs a cutting speed of 200 feet per minute?

a. 90
b. 254
c. 500
d. 807
e. 911

____ 27. What would be the theoretical weight of one foot of 1" steel square bar?

a. 2.500
b. 2.870
c. 2.990
d. 3.225
e. 3.400

____ 28. What number of ANSI Woodruff key seat cutter should be used to have a shank-type cutter with diameter of 7/8" and a face width of 1/4"?

a. 90
b. 254
c. 500
d. 807
e. 911

____ 29. What would be the diameter in inches of a No. "F" ANSI straight shank, jobber length drill bit?

a. .0040
b. .2570
c. .5020
d. .6770
e. .7050

____ 30. What would be the standard taper in inches per foot of a No. 3 Brown & Sharpe taper shank?

a. .004
b. .257
c. .502
d. .677
e. .705

____ 31. What is the recommended cutting speed in feet per minute for turning or milling of yellow brass which has been annealed using a carbide cutter?

a. 150
b. 220
c. 390
d. 410
e. 500

____ 32. What is the recommended cutting speed in feet per minute for milling 430F, free machining stainless steel with a Brinell hardness of 150 using a carbide cutter?

a. 150
b. 225
c. 275
d. 300
e. 375

____ 33. What is the recommended feed in inches per tooth for milling AISI 1020 plain carbon steel with a Brinell hardness of 120 using a 2" diameter end mill taking a .050 deep cut?

a. .004
b. .257
c. .502
d. .677
e. .705

ANSWERS TO UNIT TEST

1.	b	(D5)
2.	a	(D5)
3.	c	(D5)
4.	c	(D5)
5.	d	(D5)
6.	b	(D5)
7.	b	(D5)
8.	e	(D5)
9.	c	(D5)
10.	b	(D5)
11.	a	(D5)
12.	d	(D5)
13.	a	(D5)
14.	e	(D5)
15.	b	(D5)

INSTRUCTOR'S NOTE: Answers based on 22nd and 23rd editions of the Machinery's Handbook.

16.	b	(D7)
17.	d	(D7)
18.	a	(D7)
19.	e	(D7)
20.	c	(D7)
21.	a	(D7)
22.	a	(D7)
23.	b	(D7)
24.	a	(D7)
25.	c	(D7)
26.	b	(D7)
27.	e	(D7)
28.	d	(D7)
29.	b	(D7)
30.	c	(D7)
31.	e	(D7)
32.	e	(D7)
33.	a	(D7)